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Plant Operation

APPLICATIONS OF LABORATORY DATA IN PLANT CONTROL AT THE MINNEAPOLIS–ST. PAUL SEWAGE TREATMENT WORKS *

By K. L. Mick, *Chief Chemist,*

Minneapolis-Saint Paul Sanitary District

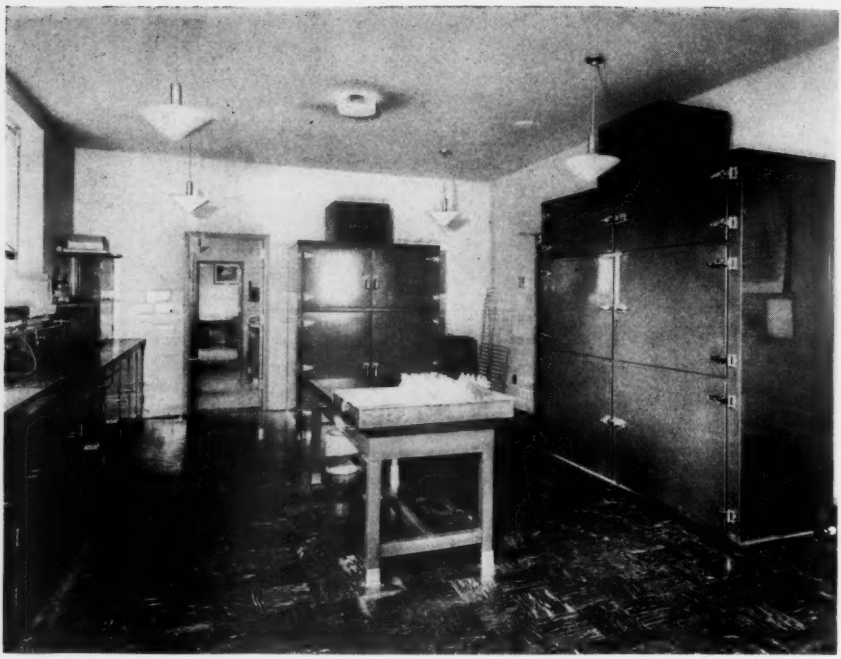
This paper briefly describes some of the applications of laboratory data in various phases of plant operation at the Twin Cities sewage treatment works. The plant has been described in considerable detail by Schroepfer in several published papers (1–4) and in the annual reports of the Sanitary District (5).

Sewage Treatment

Prior to the final design of the plant, rather extensive oxygen balance computations were made in order to predict the effect of sewage effluents of various strengths on the river at various flows and temperatures. This work was reported in the 1934 Annual Report of the Minneapolis-St. Paul Sanitary District, Chap. IV. It was done with the aid of de-oxygenation curves for the river based on a composite of Phelps' formula for the rate of de-oxygenation, and actual B.O.D. curves for the entering river water, as determined from river water samples. The de-oxygenation curves, together with recovery curves representing the balance between oxygen added by re-aeration and oxygen consumed by residual bottom deposits, permitted the computation of the maximum pollution load in the form of treatment plant effluent which could be added to the river under any given flow and temperature conditions, without resulting in the dissolved oxygen content dropping below a given minimum standard at any point on the river.

The results of these computations were plotted in the form of curves (Figs. 1–3) and show the relationship of the sewage plant effluents in terms of population equivalent, the river discharge, and the temperature, to maintain a minimum of 3 p.p.m., 2 p.p.m., 1 p.p.m., and a trace of dissolved oxygen, respectively, in the river below the Twin Cities. Fig. 1 represents the 2 p.p.m. minimum D.O. standard only. The charts for the other minimums are similar, except that the slope of the curves increases as the minimum standard increases, and vice versa. The 3 p.p.m. chart is not included here. These charts illustrate very strikingly the great effect of river water temperature on the degree of treatment required. The curves rapidly slope upward with increasing tempera-

* Presented at the Fifteenth Annual Convention of the Central States Sewage Works Association, Minneapolis, Minn., June 19, 1942.



Minneapolis-St. Paul Sanitary District. Physical, Chemical and Biochemical Laboratory.

tures. For example, for a treatment plant effluent of 900,000 population equivalent, Fig. 1 shows that at a temperature of 30° C. (86° F.) the required river discharge is more than three times that at 15° C. (58° F.) or 6,400 c.f.s. as compared with 1,950 c.f.s., to prevent the dissolved oxygen from dropping below 2 p.p.m.

The allowable plant effluent strengths in terms of population equivalent as shown in Fig. 1 include the South St. Paul packing house effluents and represent the total population load which can be added to the river from the Twin City area and still maintain a minimum of 2 p.p.m. dissolved oxygen in the river below.

A comprehensive check to determine whether the computations represented in Figs. 1–3 hold true under actual conditions of treatment plant operation is not possible as yet because of insufficient data to cover the range. However, such data as are available for the summer of 1940 indicate a satisfactory check, when the minimum dissolved oxygen content computed from Figs. 1–3 is compared with the actual observed minimum. The data for this check are given in Table I. River flow records are not yet available for the summer of 1941 so no such comparison can be made for that period at this writing.

Only a portion of the South St. Paul wastes were receiving treatment during the summer of 1940 and the Twin Cities sewage received plain sedimentation plus magnetite sand filtration of a portion. The river

flows were unusually low, 2,500 to 3,000 c.f.s. Therefore, the rather low D.O. values computed and observed for the period were to be expected. With comparable treatment being provided for the South St. Paul wastes and with the Twin Cities plant providing additional treatment, above plain sedimentation when low river flows indicate the necessity, it appears that the present tentative minimum standard of 2 p.p.m. D.O. can be easily attained. Of course, the low *minimum* D.O. values shown in Table I occurred over a relatively short distance, as the *average* D.O. values for six sampling stations along the twenty-mile stretch to the Hastings Dam were 2.75, 3.10, and 4.55 p.p.m. for July, August and September, respectively.

Considering the many variables which enter into such computations, the agreement between the computed and observed minimum dissolved oxygen in the river as shown in Table I may be regarded as satisfactory. When more data become available, the charts may be corrected if neces-

TABLE I.—*Computed and Observed Minimum D.O. in River Below Twin Cities—Summer of 1940*

	July	August	September
Pollution Entering River, Population Equivalent			
(*A*) Twin Cities			
Sewage flow, M.G.D.	113.3	109.6	102.3
River flow, C.F.S. (including sewage)	2529	2542	2811
River temperature, ° C.	24	23	20
5-day B.O.D. of plant effluent, p.p.m.	80	88	117
Population equivalent of effluent $\left(\frac{\text{B.O.D.} \times 8.34 \times \text{M.G.D.}}{0.165}\right)$	458,000	486,000	604,000
(*B*) South St. Paul and Newport Population equivalent to river [1]	495,000	495,000	495,000
(*C*) Total population Equivalent	953,000	981,000	1,099,000
Allowable Population Equivalent at Prevailing River Flow and Temperature			
From Fig. 1, for 2 p.p.m. minimum D.O.	550,000	600,000	870,000
From Fig. 2, for 1 p.p.m. minimum D.O.	780,000	820,000	1,160,000
From Fig. 3, for 0 p.p.m. minimum D.O.	1,060,000	1,130,000	1,500,000
Note: These values are plotted in Fig. 4			
Computed Minimum D.O.-p.p.m. (read from Fig. 4 for values of (C))	0.3	0.40	1.2
Observed Minimum D.O. (Avg. of Each Month's Samples)	0.2	0.25	1.4

[1] South St. Paul and Newport figure is an estimate based on limited data furnished by W. H. Cropsey, Superintendent, South St. Paul plant and was arrived at as follows:

South St. Paul plant 8 M.G.D. of 1,300 p.p.m. 5-day B.O.D. raw sewage given treatment (78% reduction in B.O.D.) for about 8 hours per day during summer of 1940.

$$\text{Population equivalent raw sewage and wastes} = \frac{1{,}300 \times 8.34 \times 8}{0.165} = 525{,}000$$

$$\text{Pop. equiv. to river} = (525{,}000 \times \tfrac{2}{3}) + (525{,}000 \times 0.22 \times \tfrac{1}{3}) = 389{,}000$$

The Cudahy plant across the river in Newport was not yet completed. Their waste is estimated at 1¾ M.G.D. and 1,200 p.p.m. B.O.D., or a pop. equiv. of 106,000.

$$\text{Total South St. Paul and Newport pop. equiv. to river} = 389{,}000 + 106{,}000 = 495{,}000$$

sary. Such charts (Figs. 1–3) should prove useful in adjusting the strength of the treatment plant effluents to meet varying river conditions; in other words, plant operation may be adjusted by throwing in

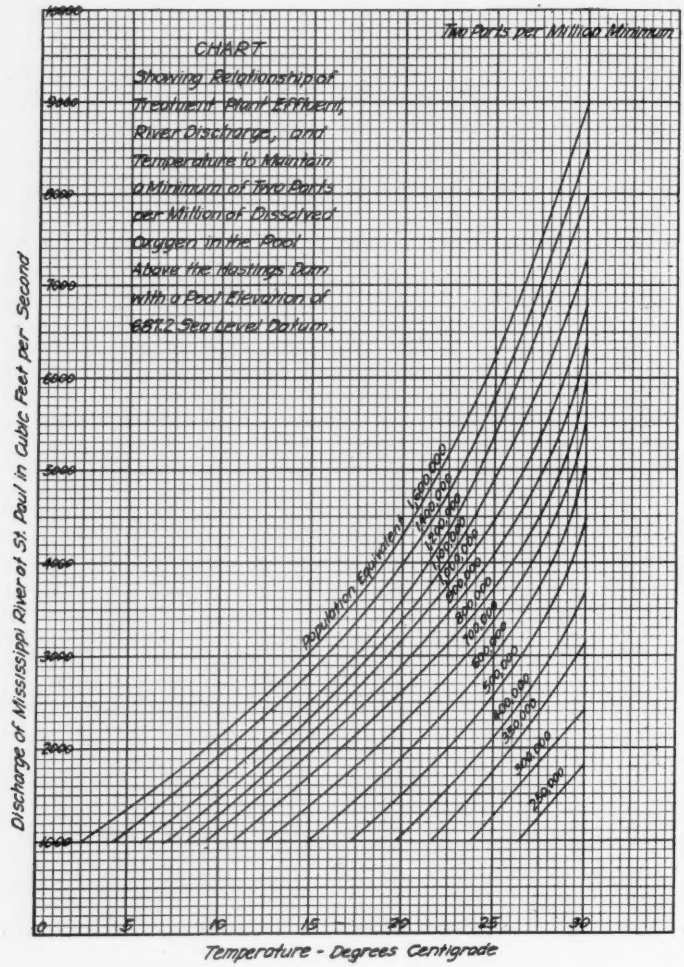


Fig. 1.

or out auxiliary processes such as flocculation, effluent filtration and chemical treatment as the needs of the river indicate, thereby providing the most economical method of operation consistent with maintenance of satisfactory river conditions.

Sludge Characteristics

One of the secrets of economical sludge disposal lies in obtaining and handling as concentrated sludge as possible. Pumping of sludge from

the settling tanks must be carefully controlled. The sludge as produced at this plant is quite variable in character and at times defies the most experienced operators to even approximately judge its concentration by visual inspection during pumping.

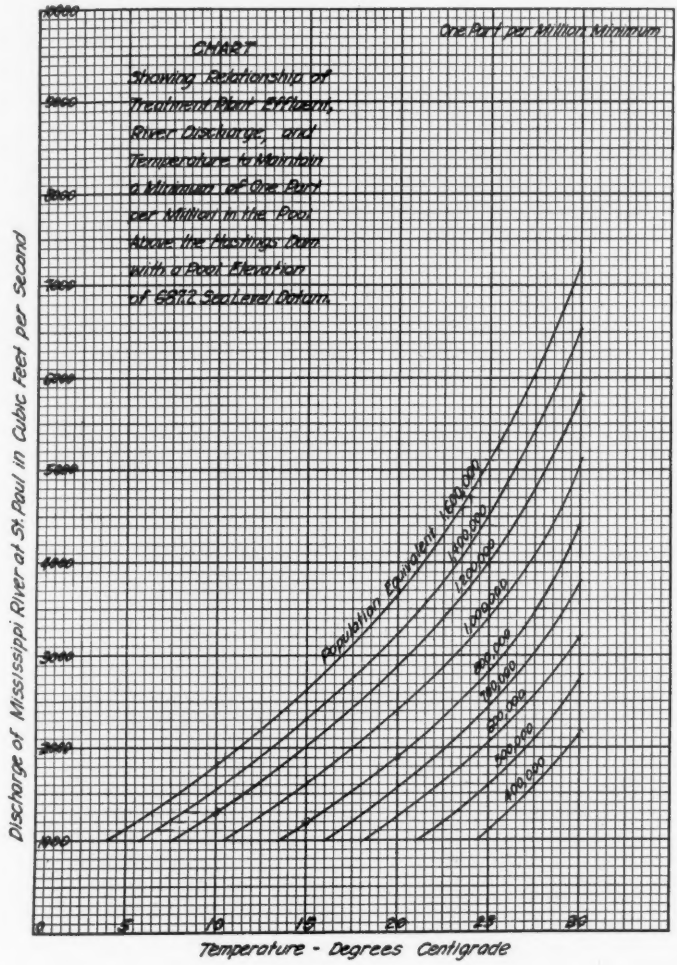


CHART
Showing Relationship of Treatment Plant Effluent, River Discharge, and Temperature to Maintain a Minimum of One Part per Million in the Pool Above the Hastings Dam with a Pool Elevation of 687.2 Sea Level Datum.
One Part per Million Minimum
Discharge of Mississippi River at St. Paul in Cubic Feet per Second
Population Equivalent 1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
Temperature - Degrees Centigrade

FIG. 2.

In order to determine when to stop pumping and thereby avoid handling too thin a sludge, and to eliminate as far as possible the variable human elements in the decision, a simple test is in use at this plant. It is essentially a determination of the specific gravity. A specific gravity of 1.025, corresponding to a sludge solids content of 7.0 to 7.5 per cent, was arbitrarily selected as the desirable point to stop pumping. The operator has a Harvard-type pan balance on a bench

near the sludge pumps. On the right hand pan is a fixed tare weight which was adjusted by the laboratory so that a 500 ml. Erlenmeyer flask filled with sludge to a mark on the neck will just balance the tare weight when the specific gravity of the sludge is 1.025.

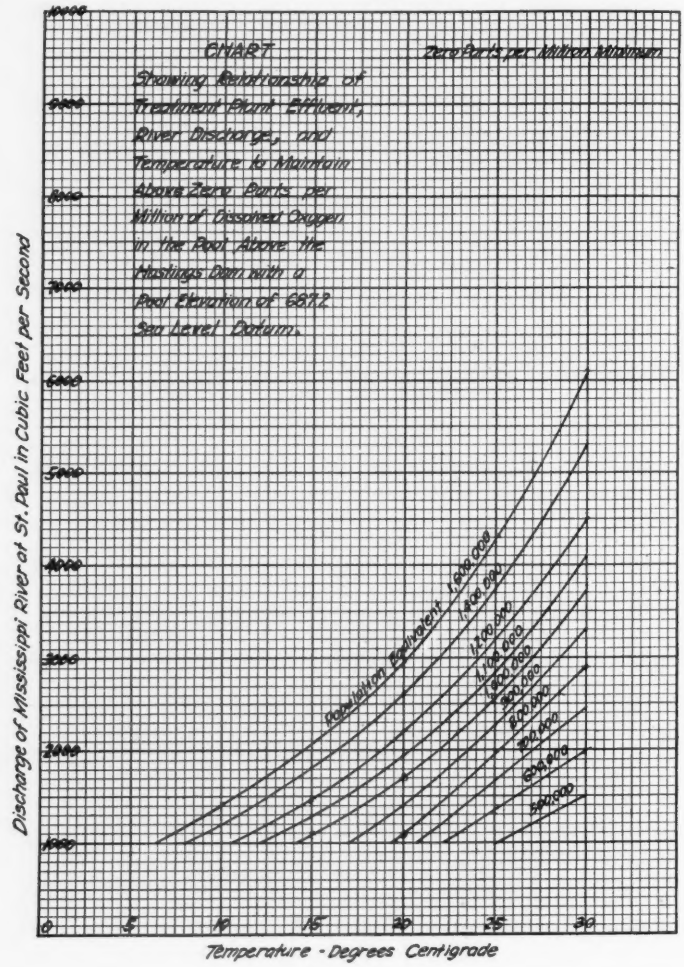


FIG. 3.

As the pumps are operating, the attendant draws off at intervals some of the sludge through the regular sampling cock on each pump. After stirring slowly to release entrained gases, he fills the flask to the mark and sets it on the balance pan. If it over-balances the tare weight, he continues pumping until further samples show that a balance has been obtained. The operator then shuts down the pump. Sludge is normally pumped from the settling tanks once each shift.

The fixed or constant tare weight for balancing the flask at a sp. gr. of 1.025 is determined as follows: a mark is scratched on the neck of the flask. Then the proper tare weight will be equal to: the weight of clean water required to fill the flask to the mark multiplied by 1.025, plus the weight of the flask empty.

This procedure for sludge pumping control is not always practicable during a few weeks of the hot summer months, when the sludge may go septic in the settling tanks if held there too long for the purpose of concentration. In addition to a decrease in settling tank efficiency due to

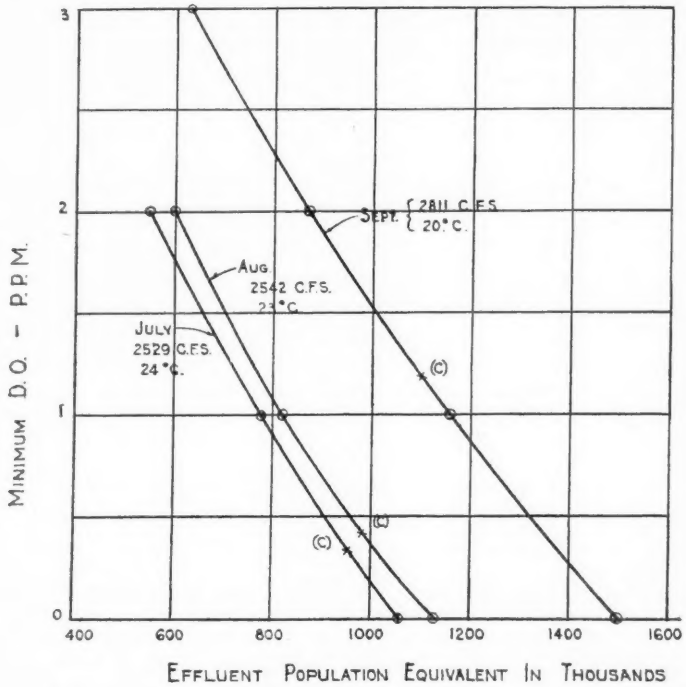


FIG. 4. Allowable effluent population equivalents for various minimum river D.O.'s. Summer of 1940.

gassing and rising sludge, the increased conditioning chemical cost in filtering septic sludge may counteract the savings obtained through more concentration. Experience to date indicates that the raw sludge should not be held after its pH drops to 5.6.

Another method in use at this plant for regulating the quality of the sludge in the interest of better filtration and incineration involves the control of grit chamber velocities. The velocities are purposely held high enough, *i.e.*, about 1.2 ft. per sec. during dry weather flows and 0.75 during storms, to permit some of the finer grit to pass on through to the settling tanks. This material in the sludge appears to benefit concentration, filtration and incineration. The Imhoff cone settleable solids

test serves to indicate the proportion of fine grit in the suspended solids going to the settling tanks. The grit settles out immediately to the bottom of the cone and may be read separately from the overlying organic solids. In 1941 the fine grit in the settleable solids entering the settling tanks averaged 0.7 ml. per liter out of a total settleable solids of 6.7 ml. per liter.

Sludge Filtration

All of the regular samples from the plant are composited for a twenty-four hour day, then analyzed and the data reported accordingly. On the basis of these samples alone the operators could see the trend of the sludge conditioning chemicals dosage only once every twenty-four hours. In order that they might have a more frequent check on the chemical dosage trend and yet not involve a large number of extra samples and analyses, the following procedure was developed.

The percentage of solids in the filter cake is one of the least variable factors in sludge filtration at this plant. Normally it varies a relatively small amount in a twenty-four hour period, except during storms when the character of the sludge changes quite rapidly. This relative constancy permits using the percentage of solids in the cake to compute the chemical dosage at four-hour intervals. To assist in this, only two extra, or special, cake samples are collected and the solids content determined, one at 7 A.M. and one at 3 P.M. They are called "short" samples. Those particular hours were selected because the laboratory staff is on duty during the day shift only, and those hours represent the maximum spread for collecting and analyzing samples in any one day.

Every four hours the filter operator computes the chemical dosage as follows:

(1) Lbs. of cake produced during previous 4 hrs. (conveyor scale reading) multiplied by the per-cent solids in the nearest "short" sample of filter cake = lbs. of dry cake solids.

(2) Per cent CaO dosage = lbs. CaO used during previous 4 hrs. (feeder totalizer reading) divided by the lbs. of dry cake solids (1).

(3) Per cent $FeCl_3$ dosage = gallons $FeCl_3$ solution used previous 4 hrs. multiplied by the lbs. dry $FeCl_3$ per gallon of solution and divided by the lbs. of dry cake solids from (1).

This computation permits each shift to see whether their chemical dosage is rising or falling as compared with the previous shift and has been one of the factors in reducing the cost of chemicals at this plant from about $240 per day in 1938 to about $110 per day at present. These computations are not used for reporting the chemical dosage on the final record sheets. The final record is based on the twenty-four hour composite samples and on the pounds of chemicals per 100 pounds of sludge solids filtered, not cake solids, which include the chemicals.

A daily sludge filtration solids balance is another practice at this plant which is of considerable value in detecting when and what part of the system is in error, *i.e.*, meters, bucket elevators, cake scales, or the samples and analyses. If all the various quantities have been properly metered, sampled and analyzed, then the total solids input to the vacuum

filters in tons should equal the total output from the filters in tons. Whenever a poor balance between input and output is obtained, efforts are immediately made to locate the difficulty. In this way any errors in the measuring equipment or in the samples are usually discovered and corrected much sooner than they otherwise would be.

The input consists of the dry solids in the sludge entering the conditioning tank plus the chemicals added. The output consists of the dry solids in the filter cake plus those in the filtrate.

During the first months of operation in 1938 a poor balance was not infrequent, the input and output varying from their average by as much as 24.5 per cent (on July 30, 1938). However, careful attention to and improvements in quantity measurements have so improved the results that the balance is now seldom off more than 4 or 5 per cent, except when some breakdown in measuring equipment occurs. Table II shows

TABLE II.—*Daily Sludge Filtration Solids Balance Percentage Variation During Each Month in 1941*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Minimum...	0.0	0.1	0.4	0.1	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.5
Maximum..	4.4	3.4	8.1	8.8	5.2	8.3	10.5	7.8	3.4	5.5	6.4	4.9
Average....	0.5	0.7	1.5	2.4	1.2	1.8	1.8	1.7	0.3	2.3	1.7	2.3

the minimum, maximum and average percentage variations in the balance during each month in 1941, based on the total input and output for the month.

FILTER CLOTH BLINDING

In filtering sludge on vacuum filters the filter cloth gradually becomes clogged or "blinded," in spite of frequent washings with clean water through spray nozzles, until finally it become advisable to change to a new cloth. The laboratory has made some studies to learn something of the nature of the material causing the blinding so that an intelligent approach might be made toward the possibility of removing it. Samples of the used filter cloths have been analyzed to determine the quantity and kind of blinding material.

A series of cloths tested in 1939 when the lime (CaO) dosage was 6 to 8 per cent of the dry sludge solids and the $FeCl_3$ dosage was 1.9 to 2.5 per cent, were found to contain an average of 15 grams of blinding material per square foot of cloth after 114 hours average service life. Lime as calcium carbonate constituted from 85 to 93 per cent of the blinding material in these particular cloths, along with 3 to 8 per cent grease, 1.6 to 3.7 per cent iron as ferric hydroxide, and 1 to 5 per cent of acid insoluble material, probably mostly silica. Examination of these cloths under the microscope revealed that many of the cloth fibers were heavily coated with a milky white material (lime carbonate) built up in icicle form. It appeared from the analyses that lime was the principal factor in the blinding of these cloths and that longer cloth life should

result if the dosage of lime could be reduced or if the lime deposits in the cloth could be removed.

A used cloth tested in 1940 with the lime dosage reduced to 4.7 per cent CaO, compared with 6.7 per cent for the cloths tested in 1939, but with identical ferric chloride dosage, was found to contain 13 grams of blinding material per square foot of cloth after 337 hours of service. Although in service three times as long, this cloth still contained somewhat less blinding material than those examined in 1939. This improvement was probably due to the 30 per cent reduction in lime dosage for the most part, and partly to increased frequency of filter washings. The blinding material in this cloth contained only 68 per cent lime as calcium carbonate, compared with an average of about 90 per cent for the 1939 cloths. However, the grease content had jumped from 5 per cent in 1939 to 24 per cent, while the ferric hydroxide and silica had changed relatively little. The lime content of the blinding material, although much reduced, still remained the predominant factor, while the grease content had risen from an insignificant to a relatively important factor.

One of the filters finally accumulated such a deposit of scale on the wooden splines that the free passage of filtrate was seriously interfered with. The deposit did not yield to hand scraping but was easily removed by syphoning a few carboys of muriatic acid into 600 gallons of water in the filter pan, with the drum revolving. Aniline oil was added as an inhibitor (300 ml. per carboy of acid) to reduce attack by the acid on metal parts of the filter.

The filters are now given an acid bath regularly at about 350 hours of cloth life, with the cloth and screen left in place on the filter, employing one or two carboys of acid. This treatment increases the economic life of the filter cloth to 500 or 600 hours and at the same time removes the scale from the screen and splines. Formerly, the screens had to be removed from the filters occasionally and sandblasted to free them from scale.

Analyses were made in the laboratory to determine the effect of the acid bath on the blinding material in the filter cloth. A cloth tested just after an acid bath at 357 hours of service was found to have been relieved of 66 per cent of the blinding material, including 95 per cent of the iron hydroxide, 87 per cent of the lime, and 60 per cent of the sand, but none of the grease. The grease may tend to coat the lime carbonate and protect it to some extent from the action of the acid. After the acid bath, what blinding material still remained in the cloth contained 64 per cent grease,* less than 2 per cent iron as ferric hydroxide, 22 per cent lime and 12 per cent sand.

After an acid bath, therefore, the predominant constituent of the residual blinding material is grease. If this grease could also have been removed by some treatment along with or immediately before or after the bath, a total of about 88 per cent of the blinding material in

* Ethyl ether extraction. Includes soaps.

the cloth tested would have been removed, instead of 66 per cent by the acid treatment alone.

Experimental work is now being conducted in an effort to remove the grease by the use of other cheap chemicals such as soda ash solution.

Over-all Solids Balance

In addition to the daily sludge filtration solids balance, a monthly over-all solids balance on the entire plant is made in order to obtain a check on the accuracy of the various samples and quantity measurements throughout the plant. This over-all solids balance by months for the year 1941 in contained in Table III, together with the yearly values for 1940. The entire 1940 balance sheet is included as Appendix E in the annual report of the Sanitary District for that year.

Very few such solids balances have been reported in the literature, perhaps largely because of the difficulty in obtaining sufficiently accurate quantity measurements and sufficiently representative samples to attain a reasonably satisfactory solids balances. The difficulties along that line have been discussed by Flower, Budd and Hauck (6), Greeley (7), and others (8). Discrepancies as high as 50 per cent were reported. In his summary on the question of solids balancing, Flower concludes among other things that:

"It is difficult to determine with reasonable accuracy the total amount of solids being handled. Quantities are computed either from the volume of the sludge pumped and its solids content or from the amount of sewage and the suspended matter removed. The results of these computations may vary widely. The reason for this variation is not apparent. Possibly it is due to inaccurate sampling and inaccurate determinations of the moisture content of the sludge.

"It appears to make a difference whether solids balances are attempted on the basis of total solids removal or on the basis of suspended solids removal. In spite of the fact that seemingly everywhere sedimentation tank performance is based on suspended solids removal it appears, from this treatment, that performance should be based on total solids removal. . . . The total solids determinations are more reliable than the suspended solids determinations. . . .

"Another source of error . . . is in the mathematical computations of the given data. The average monthly solids, suspended and total, are determined by adding the individual solids determinations and dividing by their number. . . . The solids depositions are then determined on the basis of these average figures. . . . Strictly speaking, each day's solids deposition should be computed separately or each day's solids determinations weighted, when using monthly averages."

In the operation of the Minneapolis-St. Paul plant, an attempt has been made to avoid the sources of error mentioned in Flower's conclusions, and with some degree of success as measured by the fact that the solids balances have been reasonably close for the most part. The solids balances for 1941 as contained in Table III is more or less self-evident but some explanation may be of interest.

The quantity of dry solids in tons in the raw sewage and in the plant effluent (both total and suspended solids) are computed daily and the percentage removal figured. The values given in Table III are weighted averages for each month. They are based on 24-hour composite samples

TABLE III.—*Solids Balance for 1941*
Minneapolis-Saint Paul Sanitary District

Month	Incoming Sewage Solids—Tons (Not Including Screenings and Grit Solids)		Computed Removals					Actual Removals			
			% Removal (Including Effluent Filters)		Computed Removal, Tons (Based on Sewage Quantities and Analysis)		% Discrepancy Between Removals Computed on the Total and on the Suspended Solids Basis	Based on Raw Sludge Pumpage and Analysis			
	Total Solids	Suspended Solids	Total Solids	Suspended Solids	Total Solids	Suspended Solids		Dry Tons Raw Sludge Pumped	Dry Tons Supernatant Returned to Sewage	Dry Tons Filtrate Returned to Sewage	Net Tons Actual Removal
	A	B	C	D	A×C	B×D		E	F	G	E−(F+G)
January	11,870	4,558	28.4	73.6	3,370	3,360	0.3	3,400	53	135	3,212
February	11,380	4,423	30.0	75.9	3,414	3,360	1.6	3,124	72	129	2,923
March	12,700	5,220	30.8	72.5	3,910	3,790	3.1	4,169	67	125	3,977
April [3]	6,650	3,522	28.6	59.6	1,900	2,100	10.5	2,218	48	57	2,113
May	12,300	4,864	24.1	61.5	2,960	3,000	1.3	3,599	77	103	3,419
June	10,700	3,752	21.6	62.7	2,310	2,350	1.7	3,098	86	117	2,895
July	11,520	4,532	28.6	75.0	3,290	3,400	3.3	3,177	138	149	2,890
August	10,730	4,291	26.1	71.9	2,800	3,080	10.0	3,554	335	145	3,074
September	9,204	3,453	23.4	70.7	2,160	2,440	13.0	3,174	193	141	2,840
October	10,985	4,504	27.3	76.4	3,000	3,440	14.7	3,843	354	146	3,343
November [4]	8,517	3,069	24.2	69.9	2,065	2,150	4.1	2,769	116	109	2,544
December	11,220	4,153	25.5	73.4	2,860	3,050	6.6	3,146	126	140	2,880
Totals	127,776	50,341			34,039	35,520		39,271	1,665	1,496	36,110
Minimum	6,650	3,069	21.6	59.6	1,900	2,100	0.3	2,218	48	57	2,113
Maximum	12,700	5,220	30.8	76.4	3,910	3,790	14.7	4,169	354	149	3,977
Average—1941	10,650	4,195	26.6	70.2	2,837	2,960	5.8 [5]	3,273	139	125	3,009
Average—1940	10,500	3,980	27.5	73.0	2,899	2,915	2.8 [5]	3,360	63	140	3,157

[1] Includes 160 tons of sludge from Jan. 31 pumpage held over into February in the concentration tanks. The Jan. 31 pumpage was over 2.5 times the daily average.

[2] This does not include the 160 tons mentioned in note [1].

[3] Plant in full operation 16 days, partial operation 9 days, and shut down entirely for 5 days during April on account of sewer inspection and plant overhaul.

[4] Plant in full operation 25 days, partial operation 1 day, and shut down 4 days during November for regular inspection and overhaul.

[3] Plant in full operation 25 days, partial operation 4 days, and shut down 2 days.

TABLE III.—*Continued*

Month	Actual Removals							Discrepancy Between Computed and Actual Removals		
	Based on Bucket Elevators		Based on Scale Weight of Filter Cake							
	Dry Tons Thickened Sludge from Bucket Elevators	Net Tons Actual Removal	Dry Tons Cake Solids (Scale Wg't. × % Solids)	Chemicals in the Cake		Net Tons Actual Removal Sewage Solids as Filter Cake	Maximum % Variation from the Average of the Three Removal Bases	Tons Computed Removal (Average of Suspended and Total Solids)	Tons Actual Removal (Average from Sludge Pumpage, Bucket Elevators and Filter Cake Scales)	% Discrepancy Between Computed and Actual Removals (Based on Actual Removal)
				Tons $Ca(OH)_2$	Tons $Fe(OH)_3$					
	H	H−G	I	J	K	I−(J+K)				
January	3,103 [1]	2,968	3,160 [1]	112	36	3,012	4.8	3,365	3,064	9.8
February	2,954 [2]	2,825	3,108 [2]	133	40	2,935	2.4	3,387	2,895	17.0
March	4,260	4,135	4,279	157	43	4,079	2.1	3,850	4,063	5.2
April [3]	1,777	1,720	1,935	67	21	1,847	11.6	2,000	1,893	5.6
May	3,500	3,397	3,562	117	32	3,413	0.4	2,980	3,410	12.6
June	2,893	2,776	2,927	117	31	2,779	2.8	2,330	2,816	17.3
July	3,270	3,121	3,483	143	36	3,304	6.9	3,345	3,105	7.7
August	3,280	3,135	3,491	142	35	3,314	4.4	2,940	3,174	7.4
September	2,938	2,797	2,997	116	26	2,855	1.2	2,300	2,831	19.4
October	3,478	3,332	3,368	130	27	3,211	2.6	3,220	3,295	2.3
November [4]	2,623	2,514	2,562	91	19	2,452	2.0	2,108	2,503	15.8
December	3,018	2,878	3,233	132	27	3,074	4.4	2,955	2,944	0.4
Totals	37,094	35,598	38,105	1,457	373	36,275		34,780 [8]	35,993 [8]	
Minimum	1,777	11,720	1,935	67	19	1,847	0.4	2,000	1,893	0.4
Maximum	4,260	4,135	4,279	157	43	4,079	11.6	3,850	4,063	19.4
Average—1941	3,091	2,966	3,176	121	31	3,024	3.8 [6]	2,898	2,999	10.0 [7]
Average—1940	3,145	3,005	3,305	155	40	3,110	4.2 [6]	2,907	3,091	13.9 [7]

[5] This is the straight average of the individual monthly discrepancies. If figured on the basis of the total tons removed for the year, the discrepancies are only 4.3 per cent and 0.54 per cent, instead of 5.8 per cent and 2.8 per cent.

[6] This is the straight average of the individual monthly discrepancies. If figured on the basis of the total tons removed for the year, the discrepancies are only 1.1 per cent and 2.8 per cent, instead of 3.8 per cent and 4.2 per cent.

[7] This is the straight average of the individual monthly discrepancies. If figured on the basis of the total tons removed for the year, the discrepancies are only 3.4 per cent and 6.0 per cent, instead of 10.0 per cent and 13.9 per cent.

[8] These figures do not include the screenings and grit solids also removed by the plant. 106 tons of dry screenings and 8,950 tons of dry grit were removed. Total actual solids removal by plant = 35,993 + 106 + 8,950 = 45,049 dry tons.

collected by automatic machine samplers and on sewage volumes as measured by venturi meters.

The two different laboratory determinations, total and suspended solids, gave computed removals in fair agreement through the year, with discrepancies ranging from 0.3 to 14.7 per cent and averaging 5.8 per cent. The 1940 results were even better, the discrepancy averaging only 2.8 per cent. These percentages represent the straight average of the individual monthly discrepancies and as such probably give a better picture of the variations then does the average discrepancy based on the total tonnages for the year. The average discrepancies on the latter basis were only 4.3 per cent for 1941 and 0.54 for 1940.

The removals figured as above on the basis of the sewage volume and analyses are designated as the "computed removals," *i.e.*, they represent what should be found in the bottom of the settling tanks as sludge. The quantities of sludge actually removed from the settling tanks are designated as the "actual removals." At this plant there are three different ways in which this actual removal can be evaluated, each involving different samples and quantity measurements. The next step in the solids balance is to compute the actual removals on these three different bases and note the discrepancy between them.

First, the actual removal should be equal to the quantity of raw sludge in dry tons pumped from the settling tanks minus the dry solids in the return liquors pumped back to the settling tanks. These return liquors consist of the supernatant from the sludge concentration tanks and the filtrate from the vacuum filters. The raw sludge pumped is measured through venturi meters and sampled for solids content. The supernatant liquor is sampled for solids content and the volume is measured from the concentration tank level recorder chart. This shows the draw-off of supernatant in feet (12,800 gal. per ft.) which is then corrected for the simultaneous rate of draw-off of thickened sludge to the vacuum filters. The filtrate is sampled for solids content and the quantity is computed by difference from other measurements. The quantity of filtrate in wet tons is equal to the sum of the wet tons of sludge to the conditioning tanks (measured by the bucket elevators) and the tons of chemicals and water added, minus the tons of wet filter cake.

Second, the actual removal should also be equal to the quantity of concentrated sludge in dry tons as measured by the bucket elevator's revolution counter and the samples, minus the filtrate solids returned to the settling tanks.

Third, the actual removal should also be approximately equal to the quantity of filter cake in dry tons minus the chemicals in the cake. The filter cake is sampled for solids content and the quantity of wet cake is measured by continuous conveyor belt scales. The chemicals in the cake are computed on the basis of the following reaction:

$$\underset{162}{2\ FeCl_3} + \underset{74.1}{3\ Ca(OH)_2} = \underset{107}{2\ Fe(OH)_3} + \underset{111}{3\ CaCl_2}$$

The figures underneath are the molecular weights. Actually, there may be several other reactions but this one serves the purpose as any error would be small because the chemicals usually amount to only 4 or 5% of the total cake solids. According to this reaction, the quantity of ferric hydroxide formed from the ferric chloride is equal to the tons of dry $FeCl_3$ fed multiplied by the factor 107/162. This is assumed to remain entirely in the filter cake, as it is insoluble. Part of the lime, however, goes to form calcium chloride which is soluble and would be found in the filtrate. The quantity of $Ca(OH)_2$ remaining in the cake is assumed to be equal to the total tons of $Ca(OH)_2$ from the lime slaker (tons of quicklime, CaO, $\times$ 74.1/56) minus the tons converted to calcium chloride (tons of $FeCl_3 \times 74.1/162 \times 3/2$).

As shown in Table III, the actual removals in 1941 as figured on the three different bases outlined above agreed quite well, the maximum variation from their average ranging from 0.4 to 11.6 per cent and averaging 3.8. The corresponding average for 1940 was 4.2 per cent. Based on the grand total tonnages for the year, these discrepancies were only 1.1 per cent for 1941 and 2.8 for 1940.

The final step in the solids balance consists of comparing the "actual removals" with the "computed removals." As shown in Table III, the discrepancy between them during 1941 ranged from 0.4 to 19.4 per cent and averaged 10. The corresponding average discrepancy for 1940 was 13.9 per cent. These again are the straight averages of the individual monthly discrepancies. If figured on the basis of the grand total tons of actual and computed removals for the entire year, some of the individual monthly discrepancies (partly due to variations in sludge inventory or carry-over) are smoothed out and the average discrepancy for the year then becomes only 3.4 per cent for 1941 and 6.0 for 1940.

In general, these solids balances for 1940 and 1941 are regarded as quite satisfactory and are believed to be the result of the care taken in the operation of the plant to obtain accurate quantity measurements and representative samples and analytical procedures.

Summary

Some of the applications of analytical data to various phases of plant operation at the Twin Cities sewage treatment works have been described.

Extensive oxygen balance computations on the river made in 1934 just prior to the design of the plant were applied to the 1940 summer conditions to compute the minimum dissolved oxygen values to be expected in the river below the treatment plants. The computed minimum D.O. values were found to be in satisfactory agreement with the observed values, the latter based on actual river samples. Such computations may prove useful in adjusting the strength of the treatment plant effluents to meet varying river conditions, thereby providing the most economical method of operation consistent with maintenance of satisfactory river conditions.

A simple specific gravity test for raw sludge pumping control was described.

A procedure for providing relatively frequent checks on the chemical dosage for sludge conditioning was described, together with a daily sludge filtration solids balance as a constant check on this important phase of plant operation. A study of filter cloth blinding was reported.

A monthly over-all solids balance for 1941 was presented and discussed. With sufficient care in measurements of quantities and in obtaining representative samples and analyses, a satisfactory solids balance can be attained.

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PLANT OPERATION AT MINNEAPOLIS–ST. PAUL *

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Foreword

The Minneapolis-St. Paul Sewage Treatment Plant has been operating continuously, except for planned shutdowns of short duration, since June, 1938. The plant serves the Twin Cities and some adjoining villages (not including South St. Paul and Newport), with 900,000 population plus industries making a population equivalent of 1,200,000. Most of the sewers in the area are combined, but progress has been made in the construction of storm sewers by the two cities. All of the sewage for Minneapolis and practically all of the sewage for St. Paul flows by gravity to the plant.

This paper will be confined to the practical aspects of plant operation; more detailed information is available in previous papers and reports.[1] Although the present operating staff was engaged either in the design or construction of the plant, most of the equipment has undergone changes for improvement in operation or maintenance.

Plant

Briefly, the plant consists of screen and grit chambers, flocculating and settling tanks, effluent filters, all the facilities for chemical treatment, pre- and post-chlorinating, sludge concentration tanks, vacuum filtration and incineration of sludge with all the necessary appurtenances. The equipment for chemical treatment and chlorination has been used only for the acceptance tests and the effluent filters have been used only for acceptance tests and determination of sand losses and screen corrosion. The high river flows and higher removals by plain sedimentation than anticipated have made it unnecessary to use such equipment.

The dry weather flow varies from 70 to 150 million gallons daily, average 110 m.g.d. The flow at the plant reaches 400 m.g.d. during storms, but 200 m.g.d. has been the maximum treated.

Screen and Grit Chambers

The sewage is screened by two hand-raked racks with 6-in. openings and four mechanically-cleaned screens with 1-in. openings. Last winter the racks were hoisted clear of the sewage and this eliminated a lot of unnecessary work. Even during the thaw and storm flows since, it has not been necessary to lower the racks, although several large objects have come through. This would not hold true, however, for the first

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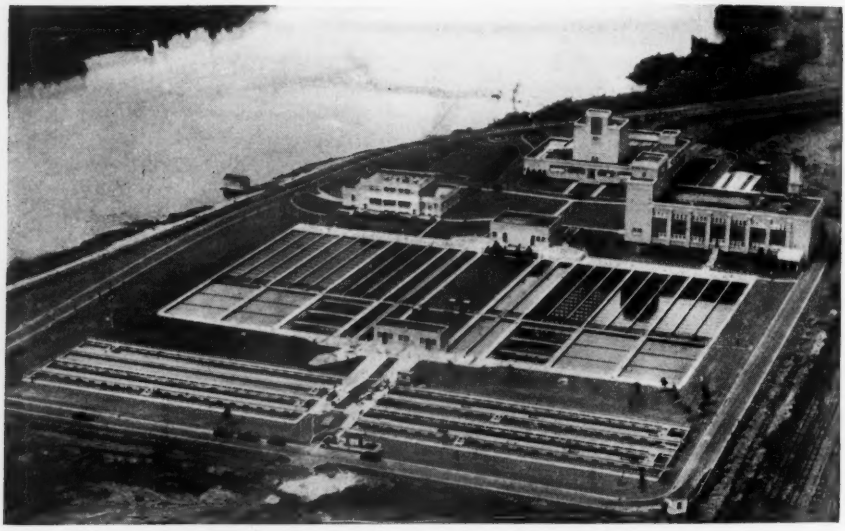
[1] *This Journal*, Nov., 1937.

years of operation. Practically all equipment in the plant subjected to shock loads is protected by shear pins.

The screenings drop on a conveyor belt and discharge into a skip hoist and are disposed of by dumping and covering with grit. Two grinders are provided but because less screenings and more grit are removed than anticipated, the covering method is more economical. The conveyor has been speeded up, as this proved a bottleneck during storm flows. The screens are automatically operated by float control of the loss of head through the screen.



Minneapolis-St. Paul Sanitary District Treatment Works.

There are eight grit chambers with mechanical scrapers that move the grit into the screw washers. The washed grit is discharged onto a belt conveyor and raised to an overhead hopper by a bucket elevator and hauled to the dump. The grit is exceptionally free of organic material and makes a good fill material.

The maximum dry weather velocity has been increased from 1.0 to 1.4 ft. per second. The velocity during storm flows is held at 0.6 ft. per second.

The level in the grit chambers was controlled by the effluent gates of the chambers for the first three years. This gave accurate control but created excessive wear on the gates and, due to the disturbance at the gates, reduced the efficiency of the chambers. The possibility of washing out the chambers was always present, especially during storm flows. The level is now controlled by the gates at the entrance to the settling tank influent channels. The loss of head compensates in part for the changes in flow and for normal flows four or five adjustments per day maintain the desired level. The operator in the screen and grit

chambers calls the operator in the pump and blower building to adjust the gates to hold a desired elevation in the open channels. Two gauges are mounted on the channel walls.

Improvements have been made in the grit bucket elevator. The grit as elevated by the screw washers generally has some free water with it. The elevator formerly would raise and discharge dry grit but not water alone, nor a mixture of grit and water. The elevator was slowed down so that water would discharge, and air jets were added to clean the buckets as they discharged. This required considerable compressed air and caused some wear by the sand blasting action. Subsequent improvements were made that allow the grit to drain in the boot hopper and then the grit is elevated without air. For dry weather flows this method is quite satisfactory.

Settling Tanks

There are six rectangular settling tanks and two combination flocculating or settling tanks with longitudinal scrapers and automatic skimmers. The removal of suspended solids has averaged 75 per cent. In the summer, two to four tanks are used, and in the winter all are in service, part of them with only sufficient flow to prevent freezing. The automatic skimmers work very well for nine months out of the year, but, because the skimmer chains are above the sewage, moisture and freezing cause breakage. Two skimmer bars of each unit are removed in November and the wipers tied up and the scum is pulled into the scum trough by hand skimmers. This requires about four to five man-hours per day and is done on the day shift.

Originally, the scum was flushed into a sump and pumped to the disposal area by two vertical sump pumps. This did not work. An air ejector was developed and no further trouble has occurred. Only enough water is added to flush the scum trough into the scum pots. Once a year we receive large quantities of elm seeds which are removed with the scum. At such times continuous removal for about 24 hours is necessary.

Sludge Removal

Throughout the plant we have been working for uniformity in all the operations. It is of prime importance to withdraw sludge of uniform moisture content during dry weather. The scrapers were run continuously for the first couple of years. This proved unnecessary and caused excessive wear on moving parts. Sludge is now pumped at 12 noon, 6 P.M., and 2 A.M. The scrapers are started at 10 A.M. and run until the evening pumping is finished, and again started at 12 midnight and stopped when the early morning pumping is completed.

To insure uniform sludge, samples are taken at each pump every 15 minutes and balanced with a weight on a scale that represents between 7 and 8 per cent solids for the volume weighed.

The inventory of sludge in the settling tanks is determined daily. The construction and size of the tanks makes it impossible to have a uniform sludge blanket in the tanks. The operator in the area takes samples before and after the evening pumping with a small grab sampler, to determine how many feet of sludge are above the bottom slab at the influent end of the tank. This does not take into account the amount in the cross-collector channel, but with controlled pumping, this method has proved rather accurate the past several months.

Filtration

The most notable improvement in equipment and operating technique, and consequent reduction in costs, has occurred in the sludge disposal processes. The highlights of the past four years will be briefly discussed.

The raw concentrated sludge, averaging 8 to 9 per cent solids, flows by gravity or is pumped from the concentration tanks to the bucket elevators and elevated to the conditioning tanks, where the sludge is mixed with lime and ferric chloride and agitated with air. The conditioned sludge flows by gravity to the six vacuum filters, each with 500 sq. ft. of filter area.

In the original layout, four filters were fed by one bucket elevator and the other two filters by the second bucket elevator. By changing the distributive piping a little, one or all filters may be fed by either elevator. The ferric chloride feeders were mounted on the tops of the bucket elevator housing and direct driven, but were later moved to the lime room and controlled by a Selsyn motor and transmission drive.

The conditioning tanks have undergone several changes. At the start, the ferric chloride solution was introduced through a pipe at the inlet end of the tank and the lime solution through a single pipe about two-thirds down the tank. The solutions were not evenly distributed and riffle boards were installed to give uniform feed across the width of the tank. The lime solution was added first, ferric chloride next; both solutions were added together; but apparently for this sludge the best results have been obtained with the ferric chloride solution added first. The average detention time the past year has been nine minutes. The original over-and-under baffles have been altered to give in addition a sidewise movement. The mixing is accomplished by low pressure air of 2 to 3 pounds. At first the air was introduced in the bottom of the tanks at three places through diffuser tubes but these became plugged. The tubes were replaced by 2-in. pipes with small holes but the plugging continued and the forward pipe was attacked by the ferric chloride. Three overhead manifolds, with several small vertical pipes extending to within a foot of the bottom, have worked well. Rags that settle out in the corners are removed by a manure hook once or twice a shift. The outlet ends of the conditioning tanks were altered by making V-weirs out of the straight weirs. This brought a more uniform sludge to the outlet pipes. The odors in the filter room were reduced considerably

by installing a larger suction fan to the conditioning tanks and bucket elevators.

The lime slakers were altered for a more desirable clinker removal system, and better flushing arrangements have been made on the improved lime solution lines.

The vacuum filter washing has been improved by changing the angle of impingement of the water on the cloth from tangential to right angles and by changing the water supply. Plant effluent is used throughout the plant for solutions, dilution, sluicing and flushing and was used for filter washing. Small particles would continually plug up the openings in the sprays, causing trouble. An unused small plant effluent pump now pumps well water from the Administration Building to an unused copperas bin, from which it is boosted to 100-lb. pressure by the pumps that would have pumped chlorine solution from the screen and grit chambers, if chlorinated copperas had been used as the conditioning agent. Experiments are now being made with a trough to allow washing while the filters are operating. The filter wash water and sludge created a problem or operating hazard by regularly overflowing the sump in the basement. Rags and heavy sludge would plug the sump pumps. After three years this drainage was discharged into the east settling tank influent channel by gravity, and is no longer a problem.

The average filter cloth life has been increased from 175 hours in 1939 to 450 hours in 1942. The blinding material is primarily lime and grease. The decreased lime dosage, better conditioning, better and more frequent washings, and acid baths the past five months, have accounted for this.

The screens and drums required periodic cleanings and until last fall this was done by removing the screen sections and sand blasting them. The splines and ports were cleaned manually. The internal pipes, however, have never shown much of a build-up. This has not been true at some other plants. An acid bath with an inhibitor was tried last fall and worked very well. Most of the filters were cleaned like new and since the first of this year the acid baths for the cloths have prevented much of a build-up on screens or drums. We have recently tried a soda ash bath in addition to the acid bath to cut the grease and further prolong the cloth life.

Experiments have been conducted to determine the optimum filter speeds for best and most economical operation. In line with this, the speed indicators of the belt drives are regularly set so that all filters rotate at the same speed for the same setting. Revolution counters have been attached to the trunions and parallel records indicate hours and revolutions. The usual method of recording filter yield as pounds per square foot per hour is only relative unless the speed of the drum is taken into account.

The conditioning chemicals used have been lime and ferric chloride although the plant is fitted to use chlorinated copperas or ferrisul. One car of ferrisul has been used and works satisfactorily, but is not as

economical as ferric chloride. Ferric chloride alone has been tried and could be used if lime shipments were delayed, but is more expensive.

The ferric chloride has been progressively decreased from the 3.17 per cent average for the last half of 1938 to 1.1 per cent for the first five months of 1942. Likewise, the lime percentages have been reduced from 10.3 to 3.24 in the same period. These percentages are based on dry solids. At the start of operation, with large amounts of chemicals, the cake was about ⅜-in. thick and the period between washings 8 to 24 hours. The cake was tough and caused belt plug-ups and other operating difficulties. The cake now is less uniform in thickness and is about 3/16-in. thick. Experiments at our plant show that it is more economical to operate more filters at a lower yield rate, with more frequent washings, than to apply enough chemicals for higher yields. If a satisfactory method of washing without taking the filter out of service is developed, this will have the same net result as using one or two more filters.

Several reasons for reduced chemicals have been previously mentioned but two of the most important factors were teaching the filter operators how to use a slide rule and the adjustment of chemicals to the characteristics of the sludge. The solids, volatiles, consistency, etc., are not constant. Some of the anticipated problems have been satisfactorily solved, but the vagaries of raw sludge are still many. Solids in the cake are determined by short samples twice daily and once on weekends and holidays and the results are used by the operators in computing the percent chemicals used. The percentages are computed every four hours and for the seven-hour run. This has had a remarkable practical effect, as well as psychological, in obtaining uniform and economical operation.

For some time Buechner funnel tests were made frequently to determine their feasibility for chemical control but were abandoned a year ago because of the erratic results.

Pipe Lines

In our plant there are pipe lines carrying some 25 different substances and practically all piping is exposed. Some lines cause no particular problem and with ample flushing facilities, with high pressure water and air, the raw sludge lines have worked well. The distribution lines from the conditioning tanks to the vacuum filters and the filtrate lines under pressure have presented a periodic problem. The conditioned sludge lines build up with layers of calcium carbonate and grease. This varies from ½-in. to 2 in. in some of the lines and for the past two years the plant has been shut down every six months to clean these lines. A "Roto-Rooter" sewer cleaning machine has worked effectively on most of the lines and acid has been used in others. The carbonate in the filtrate lines is harder and periodic cleaning with acid probably will be the best solution.

Incineration

There are three rabble type incinerators, each with eight hearths. For the normal load of 300 tons of filter cake per day, two incinerators are used, and for peak loads of 500 tons, all are in operation. There have been several improvements in the equipment since the acceptance tests, to improve operating conditions and maintenance and to effect reductions in operating costs. From the start, it became apparent that no oil would be required to support combustion and that dissipation of excess heat was the problem. The preheaters on two incinerators have been removed and converted into cooling towers with the elimination of the combustion air fans and reduced use of the hot gas fans. A substantial power saving has resulted.

Early rabbling troubles on Hearth No. 1 have been eliminated by larger teeth and finer water sprays. Sprays have been removed from Hearth No. 2, reducing cracked rabble arms and maintenance of brick work.

The average daily ash removal of 45 tons and peaks of 80 tons is sluiced to dumping areas near the plant. For the past six months the ash has been conveyed through a line 2000 ft. long.

Lubrication and Cleaning

All lubrication, except grease-packed motor bearings, is done by the assistant operators in each building. The equipment is divided evenly and the responsibility rests with one individual, so that accurate records are maintained. The motors are lubricated by the electrician during overhaul or by two trained utility operators.

The main cleaning is done by laborer-attendants and the areas divided among the shifts, and certain equipment is assigned to individuals to keep clean. This system of individual responsibility has worked very well.

Effects of War

About a year ago the use of tank cars for ferric chloride storage was curtailed and a 16,000 gallon storage tank was built. At any time we expect a 24-hour unloading order to appear, eliminating car storage. A small "squeegee" type pump has been purchased to elevate the ferric chloride from the large storage tank to the two 1000-gallon tanks in the lime room.

As in other plants, we have been reduced to practically no supplies without a high priority. The purchase of high temperature castings for the incinerators has been the most critical problem, and although we have sufficient parts for some time, other schemes of disposal of the sludge cake have been thoroughly investigated.

The many visitors of the past years have been reduced to a few, due to the necessary plant restrictions and other protective measures which have been instituted on the whole system.

Future Considerations

This paper in no way covers all of the problems encountered, and is given for the whole operating staff.

When materials are available, there are several improvements that will be made, such as—conversion of the last preheater to a cooling tower; use of waste incinerator heat for plant heating, and possible power generation; improved flow conditions from conditioning tanks to vacuum filters; improved flow conditions from the concentration tanks to bucket elevators . . . and many others that have been studied.

For the past two years experiments and studies have been made in conjunction with the Farm School of the University of Minnesota on the limitation and economies of sludge cake as a fertilizer.

BAFFLE WALLS BEFORE INLETS OF TRAVIS HYDROLYTIC TANKS AND WHAT THEY DO AT CAIRO, EGYPT

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Editor's Note.—This short paper is of unique interest, as it shows that the sewage works operator thinks of ways to improve his plant's operation, even in the midst of war, and with the enemy near. We hope that no bombs will ever destroy the baffles that produced such a remarkable improvement in efficiency of the primary settling tanks at Cairo.

Sewage from Cairo is collected and passed through two main collectors, and then pumped through two rising mains to the Sewage Disposal Works at Gabal el Asfar, 26 kilometers from the center of the city. It is a strong, septic, domestic sewage. The daily flow of sewage is averaging about 120,000 cubic meters (31.7 million U. S. gallons). The Sewage Disposal Works consists of two sets of sedimentation tanks, each of which is about 10,000 cu. m. capacity; one set is Travis hydrolytic tanks (septic tanks) treating about 70,000 cu. m. of sewage per day; the other is Leipzig plain sedimentation tanks treating the remaining daily discharge, *i.e.* about 50,000 cu. m. In addition to the settling tanks there are eight gravel filter beds of 5,700 sq. m. area and 2 m. deep, which treat about 4,000 cu. m. per day of settled sewage. The effluents from all these works are mixed and then pass directly to irrigate a farm of about 1760 acres area, where citrus fruits, olives, palm-trees, forests, cereals, etc. grow.

The Travis tanks present are six in number, each of which is divided into two compartments in such a manner that the entire flow of sewage passes the first compartment, and then at the outlet weir is divided in the ratio of 80 per cent which passes directly to the farm and is known as "80 per cent" effluent, and 20 per cent which flows to the second compartment, which is one-fifth of the total capacity, to receive additional settling before a portion of about 4,000 cu. m. of the effluent produced, and which is known as "20 per cent" effluent, is filtered in the percolating filters.

These tanks are now operated mainly as plain sedimentation tanks and not as septic tanks as they were originally designed in 1910. Sewage is distributed through these six tanks via a main supplying channel 2 m. in width, 1.5 m. in depth, and 65 m. in length. Each tank has two isolated inlets which are 2 m. below the water level in the supplying channel. The width of each inlet is 85 cm., and each inlet is shut and opened by means of a sluice gate.

Some months ago an effort was made to find some means for increasing the settling efficiency of these tanks, as the dispersion of flies, which is especially noticeable in April, May, September, and October, is attributed to the suspended solids that are deposited on the surface of the soil, forming a layer of sludge on which flies lay their eggs.

It was very simple to put forward one of the following proposals:

1. Construction of new sedimentation tanks.
2. Treating the sewage with lime, or any other chemicals.
3. Additional purification works *e.g.,* bio-aeration, bio-filtration, etc.

These proposals were all rejected, however, as they would require a great expenditure of money and work which are not available in such a time of war (*stet,* Ed.).

An investigation was therefore made to determine how the efficiency of the present works could be increased, without a great expenditure of money or work. As the effluent produced from the Leipzig sedimentation tanks is satisfactory, because the retention period is a bit longer, attention was centered on the Travis hydrolytic tanks.

Sewage is introduced into these tanks under a head of about 60 cm. of water. It was found that this causes a rush which produces a great disturbance through the sewage in the tank. Eddies are clearly seen as far as half the length of the first compartment of these tanks. The efficiency is accordingly low and the effluent produced from the first compartment, which is more than half the daily flow, was not good enough as it contains a high amount of settleable solids as measured by the Imhoff cone. Baffle walls before the isolated inlets were first suggested and two of them were built of wood, at the inlets of one of the six tanks. Chemical analyses were carried out on samples of effluents from the first compartment (the so-called "80 per cent") and from the second compartment (the so-called "20 per cent"). The average results are shown in the table. Comparison is also made with effluents produced from another tank that was not provided with such devices, but otherwise operated under the same conditions:

	Effluent from First Compartment		Effluent from Second Compartment	
	Provided with Baffle Walls	Without Baffle Walls	Provided with Baffle Walls	Without Baffle Walls
Suspended Solids (p.p.m.)	130	210	128	124
Settleable Solids (Parts per 1000 by volume)	0.2	2	Nil	0.1
Oxygen Consumed in 4 hours from N/80 Permanganate at 27° C. (p.p.m.)	102	112	97	98
B.O.D. (3 days at 27° C.; p.p.m.)	325	405	305	303
Sulfides (in terms of S; p.p.m.)	23	23.8	25	24.3
pH	6.8–6.9	6.8–6.9	6.8–6.9	6.8–6.9

From the above table, it is very clear that there was a great improvement in the quality of the effluent produced from the tank provided with baffle walls before its inlets, especially in the removal of settleable solids. This can be attributed to the localized portion of the tank where such disturbance occurs and to the deflection of the currents and eddies

toward the bottom of this very restricted portion, and not as before through nearly half the total length of the tank. Consequently there was an effective increase of the actual portion of the tank in which sedimentation takes place quietly.

Many types of baffle walls were tried, but the best of all was a box-like affair very similar to what is known as a "Deflector Box," as it can easily be suspended on the walls of the tank, because the inlets are restricted on both sides of the tank, and the width of each one is only 85 cm., while the inlet chamber protrudes slightly. The front wall of the baffle, or rather the box, is 75 cm. out from the wall of the inlet chamber at the top, and 125 cm. at the bottom. It is dipped 50 cm. below the lower level of the inlet opening, and it is shut at the top 10 cm. below the water level.

Sewage Research

THE INFLUENCE OF NITRIFYING FLORA, OXYGEN AND AMMONIA SUPPLY ON THE NITRIFICATION OF SEWAGE*

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Oxidation of ammonia nitrogen to nitrites and nitrates is a phenomenon that accompanies other oxidation reactions in aerobic sewage treatment processes. It is brought about by a group of organisms which derive their energy from the oxidation of ammonia and nitrites and their carbon from either carbon dioxide or carbonates. They do not require organic compounds for their growth. However, in sewage the oxidation of ammonia and nitrites takes place in the presence of organic matter. This leads to the query: What is the effect of organic matter on nitrification?

From the early work of the Royal Commission on Sewage Disposal the conclusion was formulated that organic matters first suffer complete fermentation and subsequently a second stage ensues in which humus matters and ammonium compounds are further fermented. The first stage of fermentation must be complete before the second stage can set in, since unfermented non-nitrogenous organic matter is positively prejudicial to nitrification.

This investigation was undertaken to determine whether there is an inherent antagonism between carbon and nitrogen oxidations or whether the phenomenon is due to certain secondary factors which are responsible for the production of nitrates only after the carbon stage of oxidation is nearly complete.

In addition to the effect of organic matter some of the other factors that have an important influence on nitrification are: (1) presence of adequate numbers of nitrifying organisms, (2) ample supply of oxygen, (3) ample supply of ammonia or nitrite, (4) proper pH value, (5) a supply of carbon dioxide.

Since the pH value of sewage does not undergo material change and remains usually near the neutral point, this factor can be eliminated at the outset as a possible variable responsible for the slow rate of nitrification. An ample supply of carbonates is present in sewage, which is supplemented by the production of carbon dioxide by the oxidation of organic matter. Carbon dioxide supply, therefore, can also be eliminated as a limiting factor in nitrification. This paper will concern itself only with the possible influence of the nitrifying flora and oxygen and ammonia supply in blocking nitrification until the carbon stage of oxidation is nearly complete.

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Methods

Methods of study varied in the different experiments. In general the production of nitrates was determined in sewage, Seitz-filtered sewage, and mineral solution, with and without inoculation with activated sludge, under quiescent conditions or with aeration. When the production of nitrates under quiescent conditions was studied, the substrates were distributed into 250 ml. Erlenmeyer flasks in 50 ml. portions. In other experiments the substrates were aerated in one-liter tubes filled with sintered glass filters in the bottom. The solution of minerals used for the cultivation of nitrifying flora and determination of nitrate production had the following ingredients per liter:

Ammonium bicarbonate	0.2 gm.
Dipotassium phosphate	1.0 "
Sodium chloride	1.0 "
Magnesium sulfate	0.5 "
Ferrous sulfate	trace

Enriched cultures of nitrifying organisms were obtained by inoculating this medium with activated sludge and making repeated transfers, after a period of incubation, into the same medium.

The effect of the addition of the nitrifying flora to the 300 p.p.m. $NaHCO_3$ dilution water on the B.O.D. of sewage was studied. An enriched nitrifying flora was obtained by cultivation in the laboratory by two methods. In the first method, activated sludge was aerated for a period of three weeks, with occasional additions of urea nitrogen, until very active nitrification set in. In the second method, a small amount of activated sludge was inoculated into the mineral solution water used for the cultivation of nitrifying organisms as given above. The mineral solution was incubated until active nitrification set in, at which time transfers were made into another portion of the medium. By repeated successive transfers, enriched active nitrifying cultures were obtained.

Results

The effect of inoculation and of organic matter on nitrate production is shown in Table I. Inoculation consisted of the addition to sewage of one per cent activated sludge, by volume. Organic matter was varied (1) by using Seitz-filtered sewage and, (2) by using a mineral

Table I.—*Effect of Inoculation and Organic Matter on Nitrate Production under Quiescent Conditions.* (*Expressed as p.p.m.* NO_3-N)

Substrate	Inoculation	Days			
		1	3	4	5
Sewage	None	0	0	0	1.2
Sewage	1% act. sl.	0.6	2.4	8.0	16.0
Seitz-filtered sewage	1% act. sl.	0.8	3.2	9.6	16.0
Mineral solution	1% act. sl.	1.6	4.8	8.0	9.6

solution. The different substrates were kept under quiescent conditions. Very little nitrate was produced from the uninoculated sewage during five days incubation. The addition of one per cent activated sludge to the sewage greatly stimulated nitrate production. In the Seitz filtered sewage and mineral solution, both of which had been inoculated by the addition of one per cent activated sludge, nitrate production was not appreciably higher than in the raw sewage similarly inoculated. The results show that the important factor in the nitrification of sewage is inoculation. Sewage nitrifies slowly, because the number of nitrifying organisms is limited. When this deficiency is corrected by the addition of activated sludge, nitrification proceeds rapidly. With a properly inoculated medium, the partial or complete removal of organic matter does not appreciably alter the rate of nitrification.

TABLE II.—*Effect of Aeration on Nitrate Production from Inoculated and Uninoculated Sewage (Expressed as p.p.m.* NO_3-N)

	Days					
	0	1	3	6	8	11
Sewage	0.5	0.3	0.4	1.6	6.0	30.0
Sewage + 1% act. sl.	0.5	6.5	10.0	14.0	—	—

The next experiment attempts to show whether or not aeration is an important factor in the nitrification of sewage. The results given in Table II show that it required nearly as long for the uninoculated sewage to nitrify when aerated as under quiescent conditions. This indicates that the failure of sewage to nitrify rapidly is not due to the inadequacy of oxygen supply. In the sewage inoculated with one per cent activated sludge, nitrification was established within one day. The rate of nitrate production was higher in the aerated inoculated sewage than in the similarly inoculated sewage kept under quiescent condition in the previous experiment. Although different activated sludges were used in these experiments as a source of inoculation, containing nitrifying flora of different degrees of activity, it is probable that the slower rate of nitrification under quiescent conditions was caused by the oxygen demand of the sludge. Thus, under certain conditions with materials having a high oxygen demand, aeration may play an important rôle in the rate of nitrification.

TABLE III.—*Effect of Glucose on Nitrate Production in Mineral Solution under Quiescent Conditions. (Expressed as p.p.m.* NO_3-N)

	Days					
	1	2	4	6	8	11
Mineral solution + 1% act. sl.	0.8	0.8	4.8	4.4	12.0	—
Mineral solution + 1% act. sl. + 100 p.p.m. glucose	0	0	0.8	1.6	0.4	2.0

When 100 p.p.m. glucose is added to mineral water, and the solution is inoculated with activated sludge and kept under quiescent conditions, the rate of nitrification is greatly inhibited, as is shown in Table III. However, when this same substrate containing 100 p.p.m. glucose is aerated, the rate of nitrification is not inhibited, as is shown in Table IV. The results, therefore, show that sugar itself did not

TABLE IV.—*Effect of Glucose on Nitrate Production in Mineral Solution with Aeration.* (*Expressed as p.p.m.* NO_3-N)

	Days						
	0	1	2	3	4	6	7
Mineral solution + 1% act. sl.	0.4	0.4	0.8	2.4	2.0	3.2	6.4
Mineral solution + 1% act. sl. + 100 p.p.m. glucose	0.4	0.4	0.8	1.6	2.0	4.8	5.6

retard nitrification except indirectly by creating an oxygen deficiency. It is evident that the oxidation of carbonaceous materials and of ammonia can proceed simultaneously, provided there is an adequate nitrifying flora and an adequate supply of oxygen.

The importance of an adequate supply of ammonia nitrogen in the presence of carbohydrates on nitrification is illustrated in Table V, which is taken from material published previously (5). In this experi-

TABLE V.—*Effect of Sugar upon Nitrification of Urea Nitrogen by Activated Sludge*

Additions		First Dose (1)			Third Dose (1)		
Glucose as C	Urea-N	NH_3-N	NO_3-N	Glucose	NH_3-N	NO_3-N	Glucose as C
p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
240	0	0	0	192	0	0	204
240	6	0	7.2	192	0	0	140
240	12	0	11.2	192	0	0	40
240	24	2.4	20.0	188	0	0	0
240	36	12.0	20.0	182	0	6.4	0
240	48	16.0	24.0	176	8.0	16.0	0
240	60	20.0	20.0	176	9.0	22.0	0

(1) after 6 hrs. aeration.

ment, activated sludge containing 1,350 p.p.m. suspended solids was fed with 600 p.p.m. of glucose and varying amounts of urea nitrogen. The menstruum was a mineral solution. The mixtures were aerated for six hours, settled and the supernatant drawn off. The various sludges were fed again with 600 p.p.m. glucose, varying quantities of urea were added and the solutions were aerated for six hours. Three such feedings were made.

The ammonia, nitrate nitrogen and glucose remaining in the mixtures after six hours aeration were determined after the first and

third doses. The results show that during the first dose glucose utilization was low and was not limited by the available supply of urea nitrogen. Even with the lowest amounts of urea nitrogen added, although ammonia nitrogen was absent, considerable amounts of nitrates were produced. Due to the slow rate of sugar utilization, the nitrogen supply was not utilized by bacteria for the breakdown of sugar, and nitrification took precedence over carbon oxidation. During the third dose the rate of glucose utilization had increased and the small quantities of urea nitrogen added were not sufficient to support the breakdown of glucose. Consequently, there was no available nitrogen for nitrification. Only with the higher quantities of urea nitrogen was there sufficient additional nitrogen to support nitrification as well as oxidation of glucose. Therefore, nitrification may be inhibited when the demand for nitrogen created by the rapid utilization of carbohydrates exceeds the available supply. However, when the

TABLE VI.—*Effect of Sugar upon Nitrification of Urea Nitrogen by Activated Sludge, Measured as* NO_3-N *(in P.P.M.)*

Hrs. aeration	1st Dose		3rd Dose		9th Dose	
	Urea	Glucose + Urea	Urea	Glucose + Urea	Urea	Glucose + Urea
0	2.6	2.6	4.0	2.8	4.4	9.6
1	3.2	3.6	4.0	7.2	11.0	11.0
2	5.6	6.0	4.5	9.6	—	—
3	—	—	—	—	24.0	24.0
4	—	—	—	—	28.0	23.0
5	—	—	8.8	20.0	32.0	24.0
6	13.0	13.0	14.4	24.0	36.0	26.0

supply of nitrogen is more than adequate for the breakdown of carbohydrates, nitrification can take place simultaneously with carbon oxidation. In these experiments oxygen did not become the limiting factor because the mixtures were supplied with large quantities of air.

It was thought advisable to study the effect of sugars on nitrate production at frequent intervals during the aeration period. Forty-eight p.p.m. urea nitrogen was selected as the quantity of nitrogen sufficient for the oxidation of 600 p.p.m. glucose and leaving an excess for nitrification. To a portion of activated sludge 48 p.p.m. of urea nitrogen was added and to similar portion 48 p.p.m. urea nitrogen and 600 p.p.m. glucose were added. The mixtures were aerated for a period of six hours and the procedure repeated on a fill-and-draw basis for nine consecutive doses. At hourly intervals during the first, third and ninth doses, nitrates were determined. The results given in Table VI show that nitrification of urea nitrogen is not inhibited by the addition of glucose but that the rate of nitrate production with glucose is generally equal to and sometimes higher than with urea alone. It should be repeated that the quantities of urea added were high enough to leave

an excess for nitrification after the demand for glucose oxidation was satisfied. Air supply was also ample to eliminate oxygen as a limiting factor.

From these results it appeared that nitrification might take place simultaneously with carbon oxidation, so that the B.O.D. determination of sewage may represent both stages if an adequate inoculation with nitrifying organisms is made. A culture of actively nitrifying organisms was prepared by aeration of activated sludge for three weeks with frequent additions of urea. The clear liquor of the sludge thus treated was used as a source of inoculation. It contained 160 p.p.m. of NO_3—N and 80 p.p.m. of NH_3—N. Ten ml. of the liquor was added per liter of dilution water (300 p.p.m. $NaHCO_3$). In the control a similar quan-

TABLE VII.—*Effect of Inoculation with Nitrifying Activated Sludge Liquor on the B.O.D. of Sewage*

	Sterile Act. Sl. Liquor				Non-Sterile Act. Sl. Liquor			
	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.
0 day	8.2	—	—	—	8.2	—	—	—
1 day	8.0	75	8.2	79	8.1	75	8.2	77
2 days	8.2	114	8.2	114	8.0	111	8.2	116
3 days	8.2	131	8.2	131	7.9	130	8.2	137
4 days	8.2	144	8.2	144	7.7	162	8.2	170
5 days	8.1	156	8.2	159	6.9	217	8.2	350
7 days	8.0	161	8.2	169	5.9	290	8.2	430
8 days	8.0	164	8.2	172	5.3	323	8.2	640
9 days	8.0	168	8.2	180	5.1	339	8.2	673
10 days	8.0	188	8.2	194	5.0	347	8.2	710
11 days	8.0	209	8.2	221	4.9	345	8.2	840
14 days	7.7	615	8.2	676	—	—	—	—
16 days	8.0	630	8.2	652	—	—	—	—

tity of the liquor was added after sterilization in an autoclave. A series of dilutions of sewage were made with these two dilution waters. The results are presented in Table VII.

The dissolved oxygen in the blanks, which had received the sterile activated sludge liquor, remained fairly constant during the 16-day incubation period, while the dissolved oxygen in the dilution water with the non-sterile liquor decreased from an initial value of 8.2 to 4.9 p.p.m. in 11 days. This was attributed to the oxidation of ammonia introduced by the activated sludge liquor together with the actively nitrifying organisms. The rapid increase of nitrites and nitrates in the blanks containing the non-sterile liquor, as indicated in Table VIIa, confirms this view. The B.O.D. values were calculated both on the basis of the dissolved oxygen in the blanks for corresponding days and on the basis of the initial D.O. values in the dilution water. The latter method of calculation is based on the assumption that if no ammonia nitrogen was introduced by the liquor containing the nitrifying organisms, the dis-

solved oxygen in the blanks would have been constant. Since this liquor was obtained after aerating activated sludge with urea and water for a period of three weeks, the oxygen demand of the liquor due to organic matter was negligible. The oxygen depletions in the blanks, due to the oxidation of ammonia nitrogen, are also registered in the oxygen depletion of the dilution water containing the sewage, because both contained the same amounts of activated sludge liquor. If the initial blank is used, the oxygen depletion, due to the oxidation of ammonia nitrogen in the sludge liquor, is registered in the depletions containing the sewage sample.

TABLE VIIa.—*Effect of Inoculation with Nitrifying Activated Sludge Liquor on the Production of Nitrites and Nitrates in Sewage Diluted for B.O.D. Determination*

Days	Sterile Liquor				Non-Sterile Liquor			
	Blank		With Sewage		Blank		With Sewage	
	NO_2 p.p.m.	NO_3 p.p.m.	NO_2 p.p.m.	NO_3 p.p.m.	NO_2 p.p.m.	NO_3 p.p.m.	NO_2 p.p.m.	NO_3 p.p.m.
3	0	2.0	0	2.0	0.3	2.0	0.4	2.0
8	0	2.0	.015	2.0	0.75	2.0	1.25	2.0
10	0	2.0	.075	2.0	0.75	2.4	1.25	2.4
14	0	2.0	1.75	2.0	—	—	—	—

The B.O.D. values obtained by either method of calculation are higher when the sewage flora was supplemented with the actively nitrifying flora. The difference was higher when the calculations were based on the initial dissolved oxygen value. Considerably higher values were obtained even with the five-day B.O.D. in the inoculated series than in the uninoculated sewage. The differences became greater with longer periods of incubation. The results plotted in Figure 1 show, for the non-inoculated control series, the normal type two-stage B.O.D. curve, *e. g.*, a rapid initial increase followed by a period of slow increase and finally a very rapid rise at the end. The values were identical for the inoculated and uninoculated series for the first three days, thereafter the values diverged, due to the rapid rate of B.O.D. increase in the inoculated series. There was no indication of a flattening of the curve during the middle period of incubation in the inoculated series. Since all other factors were the same in these two series, the differences are to be attributed to the introduction of actively nitrifying organisms. The normal type of B.O.D. curve obtained with sewage, which has been attributed to the oxidation of carbonaceous material in the first stage and the oxidation of ammonia nitrogen in the final stage, appears to be due to the fact that sewage normally contains fewer nitrifying organisms in comparison with the carbon oxidizing organisms and the rate of development of the nitrifying organisms is slow. When this discrepancy is obliterated by the addition of large numbers of nitrifying organisms, oxidation of carbonaceous materials and of ammonia can

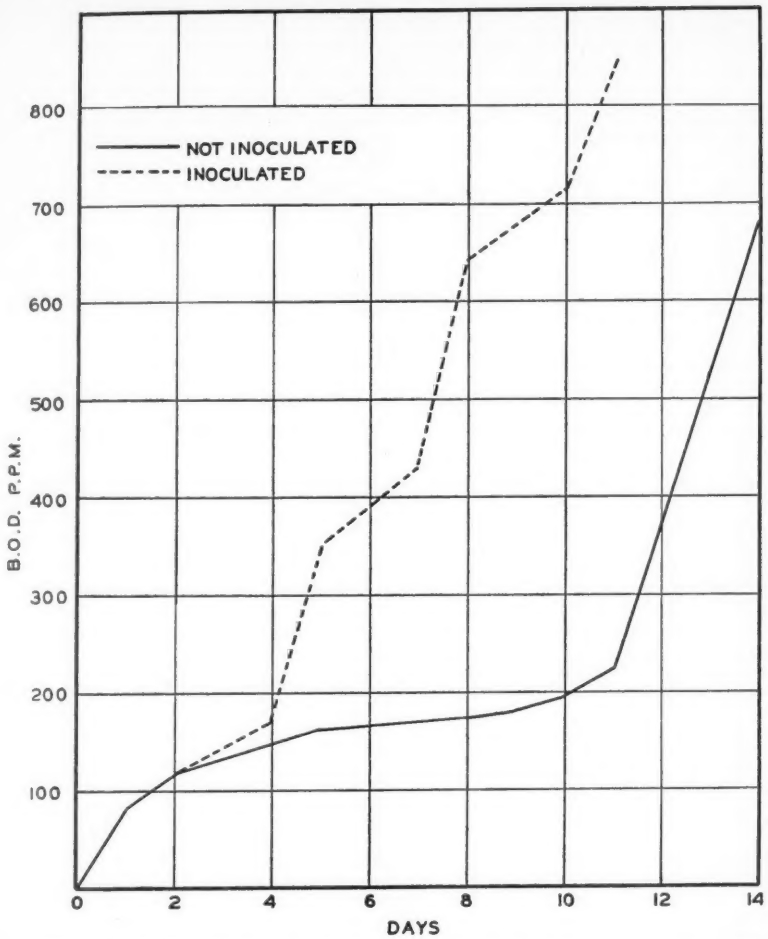

FIG. 1.—The effect of inoculation with nitrifying activated sludge liquor on the B.O.D. of sewage.

proceed simultaneously. That this was actually the case is shown by the rapid increase in nitrites and nitrates in the inoculated series after the third day of incubation while in the uninoculated series nitrites and nitrates were not produced until after the eighth day.

The above experiment was repeated under somewhat different conditions. A nitrifying flora was developed by inoculating the mineral solution containing ammonia with a small quantity of activated sludge. After incubation under quiescent conditions until nitrification was established, transfers were made into new mineral solution containing ammonia. This procedure was repeated several times until an active nitrifying flora was obtained. The culture thus obtained for inoculation of the dilution water (300 p.p.m. $NaHCO_3$) contained 2 p.p.m. of am-

TABLE VIII.—*Effect of Inoculation with Nitrifying Flora on the B.O.D. of Sewage*

Days	Sterile Culture				Non-Sterile Culture			
	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.	Blank D.O. p.p.m.	B.O.D. p.p.m.
1	7.9	139	7.9	139	8.0	152	8.0	152
2	7.8	209	7.9	215	7.8	225	8.0	232
3	7.8	255	7.9	260	7.8	269	8.0	278
4	7.9	265	7.9	265	7.7	290	8.0	318
5	7.9	279	7.9	279	7.5	307	8.0	365
7	7.8	295	7.9	305	7.5	400	8.0	483
9	7.9	316	7.9	316	7.4	456	8.0	557
11	7.8	426	7.9	450	7.4	565	8.0	722
12	7.5	497	7.9	567	7.1	495	8.0	697
14	7.6	600	7.9	645	7.0	500	8.0	720
16	7.3	620	7.9	758	7.0	525	8.0	750
18	7.3	585	7.9	640	7.0	616	8.0	845

monia nitrogen and 20 p.p.m. of nitrate nitrogen. Ten milliliters of the culture was added per liter of the dilution water. In the control the culture was autoclaved before addition to the dilution water. A series of dilutions of sewage were made with the two dilution waters

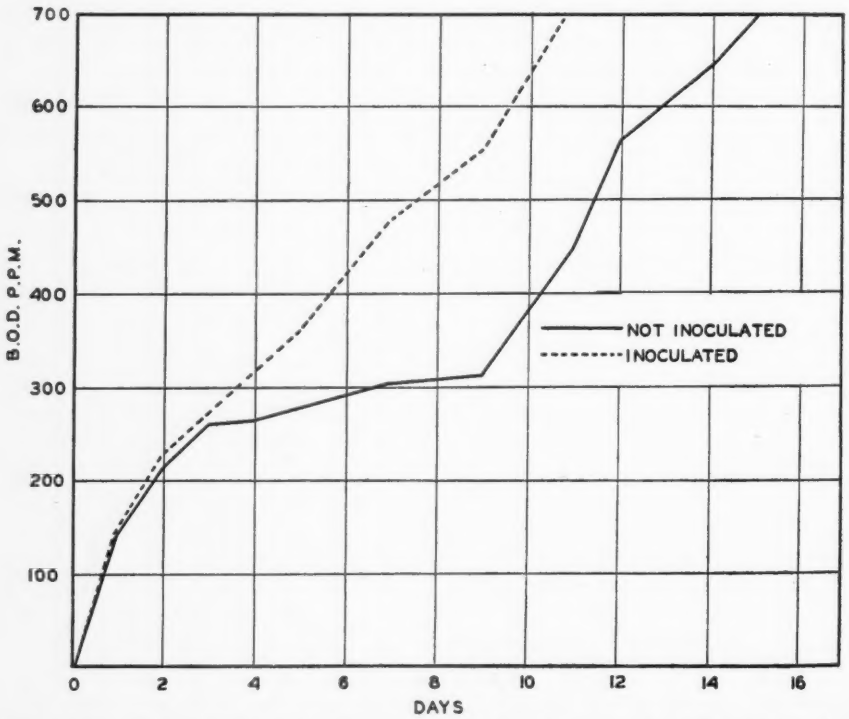

FIG. 2.—The effect of inoculation with an active nitrifying culture on the B.O.D. of sewage.

thus prepared. The results are given in Table VIII and Figure 2. The depletion of dissolved oxygen in the blanks (containing the culture) during incubation was not so great as in the previous experiment. This is to be attributed to the smaller amount of ammonia nitrogen contributed by the culture to the dilution water. Again, the B.O.D. values were calculated on the basis of the initial dissolved oxygen as well as on the basis of dissolved oxygen content in the blanks after different

TABLE VIIIa.—*Effect of Inoculation with Nitrifying Flora on the Production of Nitrites and Nitrates in Sewage Diluted for B.O.D. Determination*

Days	Sterile Culture				Non Sterile Culture			
	Blank		With Sewage		Blank		With Sewage	
	NO_2-N p.p.m.	NO_3-N p.p.m.	NO_2-N p.p.m.	NO_3-N p.p.m.	NO_2-N p.p.m.	NO_3-N p.p.m.	NO_2-N p.p.m.	NO_3-N p.p.m.
4	0	.3	.06	0.3	0.4	.3	0.1	0.4
7	0	.025	.01	1.0	.025	0.2	0.16	0.7
18	.05	.16	0.3	0.16	0	0.35	0	0.7

periods of incubation. The results show the normal type of B.O.D. curve for the uninoculated series with the flat part of the curve extending from the third to the ninth day. The B.O.D. of the inoculated series, however, increases without any apparent retardation during the middle period. The nitrite and nitrate values given in Table VIIIa show a rapid nitrification during the early periods of incubation in the inoculated series.

TABLE IX.—*Effect of Inoculation with a Nitrifying Culture on the B.O.D. of Sewage B.O.D. in p.p.m.*[1]

Days Incubation	I 1% Inoculum	II 1% Inoculum Sterilized	Difference	III 10% Inoculum	IV 10% Inoculum Sterilized	Difference
1	77	71	6	76	70	6
2	101	91	20	114	92	22
4	132	113	19	183	115	68
5	150	120	30	207	121	86
6	167	135	32	256	133	123
8	230	150	80	300	145	155
10	280	165	115	370	160	210
12	520	212	308	520	210	310
14	600	405	195	600	335	265

[1] Calculated on the basis of initial D.O. in the dilution water.

The effect of adding two different quantities of a nitrifying culture to the dilution water on the B.O.D. of sewage is shown in Table IX. The quantities of culture added are on the volumetric basis. The procedure was otherwise the same as in the preceding experiments. The results with the 1 per cent and 10 per cent sterilized inocula are identical.

The results with the unsterilized inocula, however, show marked differences both in comparison with their corresponding controls as well as in comparison with each other. Appreciably higher B.O.D. values were obtained in the inoculated series even during the first five days incubation. The values with the 10 per cent inoculation were markedly higher than with 1 per cent inoculation. The five-day B.O.D. values with the 1 and 10 per cent inocula were 25 and 71 per cent higher, respectively, than the corresponding control. With longer periods of incubation the differences became greater.

Discussion

The conclusions drawn from this investigation are in accord with Barritt (1), who suggested that the inhibitive action of organic matter on nitrification can be accounted for by the accumulation of carbon dioxide, ammonia and deficient aeration. Bömecke (2) could not confirm the claim of previous investigators as to the lethal effect of soluble organic matter on the nitrifying organisms. Jenkins (6) did not consider the complete absence of carbohydrates as essential for nitrification on the basis of studies on the oxidation of sucrose in sectional percolating filters. O'Shaughnessy and Roberts (8) observed that the nitrification stage of sewage corresponded with the separation from the liquor of visible suspended matter settling in the form of floc. They attributed a significant role to these "humus bodies" in promoting nitrification, for when such "humus bodies," collected by filtering activated sludge and trickling filter effluents, were added to trickling filter effluent there was no indication of two-stage oxidation, but nitrification started between two to four days incubation, when presumably carbon compounds were undergoing oxidation. It is not clear from the authors' discussion whether the stimulation of nitrification is due to a necessary chemical ingredient in the "humus bodies" or to the presence of nitrifying organisms. That the former is not the case is shown by the ineffectiveness of sterilized activated sludge or humus from trickling filter to promote the nitrification of sewage.

The results obtained on the effect of seeding on the B.O.D. curve are not in accord with results published by Theriault and McNamee (9) and Thomas (10). The differences can be accounted for by the activity of nitrifying flora introduced as an inoculum.

Theriault and McNamee (9) concluded that nitrification in sewage mixture with an inoculum of nitrifying organisms did not proceed to an appreciable extent until after approximately a week of incubation. The first stage of the deoxygenation curves were similar, irrespective of inoculation. The delay in nitrification was, therefore, attributed to the repressive effect of organic matter on nitrification and not to the scarcity of nitrifying organisms present. Since these authors had no adequate controls without inoculation, it is difficult to determine whether the inoculum had any effect on the nitrification stage itself.

Thomas (10) similarly obtained two-stage B.O.D. curves with inoculated sewage. The inoculum consisted of sewage previously kept under aerobic conditions for a period of three weeks. The B.O.D. values obtained during the first nine days of incubation (carbon stage of oxidation) where practically the same in the inoculated and uninoculated sewage. The nitrification stage started about a day earlier and proceeded more rapidly in the inoculated series. Even when activated sludge effluent was inoculated there was no appreciable oxygen uptake for a period of about eight days, corresponding to the period required for the start of nitrification in the inoculated sewage. Therefore, the completion of carbon stage of oxidation in the activated sludge effluent did not permit the nitrification stage to set in from the beginning of the incubation period, even when additional inoculum was used.

Mohlman, Edwards and Swope (7) reported a two-stage B.O.D. curve for an activated sludge effluent. The time required for the completion of the first stage was shorter (5 days) and the magnitude of the first stage demand was lower than in the sewage samples. Since the carbon stage of oxidation is presumably completed in the activated sludge effluent, it is difficult to see how the initial stage in this case can be attributed to carbon oxidation. It is more probable that the two stages here mark the nitrate production stages, rather than carbon oxidation and nitrification stages. The nitrite and nitrate values, found by these authors in the samples with the activated sludge effluent, support this view. That a clear cut separation of the carbon and nitrification stages cannot be made in the B.O.D of sewage is indicated by the increase of nitrites during the latter part of the first stage demand.

The evidence presented from the various methods of approach, point to the conclusion that nitrification can take place simultaneously with the carbon stage of oxidation, provided: (1) that the oxidation of the organic matter does not deplete the oxygen supply, or (2) the available nitrogen supply and (3) that there is an active nitrifying flora present. One or more of these factors are usually responsible for the occurrence of nitrification only after the oxidation of carbonaceous material, or for the absence of nitrification.

The theoretical implication of this conclusion is that the organic matter of domestic sewage does not contain constituents which are inimical to nitrifying organisms. Neither does glucose *per se* have an adverse effect on nitrification. Therefore, when nitrification is delayed or is absent in the oxidation of sewage in the various types of treatment processes under practical conditions of operation, the explanation is to be sought in one or more of the above reasons mentioned. It should be stated, that the discussion of the factors influencing nitrification does not imply that nitrification is a necessary desideratum in sewage treatment processes. But a clear understanding of the factors involved in nitrification is helpful in the proper interpretation, while the presence or absence of nitrates gives valuable information as to which of the factors are playing an important role. It further follows that the appearance of nitrates does not necessarily indicate the completion of

the oxidation of organic matter in sewage, because under certain conditions nitrates may be produced simultaneously with the oxidation of organic matter. Conversely it does not necessarily mean that when nitrates are not produced, the organic matter is not properly oxidized.

Plain aeration of sewage requires one to two weeks before nitrates are produced. This is a common experience in the starting of new activated sludge plants. The time required for the establishment of nitrification in these cases does not represent the retarding effect of carbonaceous oxidation, nor is it due to a deficiency of oxygen or ammonia. It merely represents the time required for the nitrifying organisms in sewage to develop in sufficient numbers. The numbers of nitrifying organisms which occur most frequently in sewage, according to Hotchkiss (3), are about 100 per ml. A rapidly growing organism can bring about, under favorable environmental conditions, considerable changes within comparatively short time starting with such low numbers. However, the nitrifying organisms are very slow growing organisms. Hence, when the initial numbers are low, it takes them 1 to 2 weeks to develop sufficiently to produce measureable amounts of nitrates. This is also the explanation of the delayed nitrification of sewage in the B.O.D. determination. Here, the few nitrifying organisms that are present in the sewage are further reduced in numbers per unit volume by the dilution water. The activities of organisms responsible for the oxidation of carbonaceaus materials, which are present in larger numbers initially and are more rapid growers, are not so adversely influenced by the dilution factor.

If the delayed appearance of nitrification in the B.O.D. is due to the period necessary for the development of the few nitrifying organisms present in the diluted sewage, it follows that whenever the nitrifying organisms are high, carbon and nitrogen stages of oxidation will overlap and the 5-day B.O.D. may represent the oxidation of a portion of ammonia nitrogen as well as that of carbonaceous material. Fortunately, this does not happen in the B.O.D. determination of sewage samples. However, the B.O.D. of effluents from oxidation devices manifests only a one-stage oxidation curve. This has been interpreted as an indication of the completion of carbonaceous oxidation. It can also be due to presence of large numbers of nitrifying organisms in such effluents. In other words, even if the carbon stage of oxidation was not complete, a single-stage curve could be obtained. Experimental evidence indicating this to be a distinct possibility has been produced by the obliteration of the two-stage B.O.D. curve in the oxidation of sewage in the presence of nitrifying organisms. The 5-day B.O.D. values of sewage do not represent the oxygen consuming power of that sewage undergoing oxidation in the presence of an active nitrifying flora, such as in trickling filters and the activated sludge process. It may also introduce considerable discrepancy between the calculated and actual oxygen demand of a sewage when the sewage is oxidized in a stream. It is not the purpose of this paper to advocate the addition of nitrifying organisms in the B.O.D. determination nor the use of longer periods of

incubation to include the oxygen demand of ammonia nitrogen in the sewage, except to call attention to the possibility that under certain conditions this may introduce important discrepancies between the determined oxygen demand and the actual exerted demand.

Another error may arise from this source when the B.O.D. of an effluent from a conventional trickling filter is compared with that from a high-rate filter. The 5-day B.O.D. of an effluent from a conventional type of filter will be influenced considerably by the oxidation of ammonia nitrogen, while the 5-day B.O.D. of an effluent from a high-rate filter will probably include only the carbon stage of oxidation. Therefore, comparisons of the efficiencies of the low-rate with high-rate filters will not be on an equal basis. Since it is not possible to eliminate the nitrifying organisms in the effluent from a conventional type of a filter, it would be interesting to compare the B.O.D. values of the effluents from the two types of filters with longer incubation periods to include the nitrification stage in both cases. The B.O.D. values of effluent from nitrifying and non-nitrifying trickling filters and activated sludges may also show considerable variations due to this factor.

The oxidation of carbonaceous materials may also exert an indirect influence on nitrification by taxing the limited oxygen supply. In activated sludge aeration tanks the late appearance or the complete absence of nitrates may be attributed to this factor. During early periods of aeration a high oxygen demand is exerted by the oxidation of carbonaceous materials, lowering, or completely removing dissolved oxygen from the liquor. Nitrates are usually not present during this stage. When the active oxygen utilization period is completed the dissolved oxygen increases and nitrates begin to appear. Ingols (4) has shown that low dissolved oxygen values (.2–.7 p.p.m.) retard but do not inhibit nitrification. These results were obtained by aerating urea nitrogen with a thoroughly oxidized activated sludge in the absence of sewage. It is doubtful whether even small amounts of nitrates could be produced with such low dissolved oxygen contents if active carbonaceous oxidation were taking place simultaneously with nitrification. This is not because of inherently antagonistic action between carbonaceous oxidation and nitrification, but because when a rapid oxidation of carbonaceous materials takes place, it is doubtful whether a D.O. tension of .2–.7 p.p.m. would be sufficient to maintain the floc completely aerobic. When the accumulation of organic matter in the floc (adsorption) is great, it may require a higher dissolved oxygen tension to keep the floc completely aerobic and thereby allow nitrification to take place. This is probably why certain sludges do not nitrify even with 4 to 5 p.p.m. dissolved oxygen. A short aeration period will likewise result in the accumulation of the oxidizable material in the floc, irrespective of the dissolved oxygen content of the surrounding water, and prevent the oxygen from becoming available for nitrification.

In the trickling filter a similar situation exists. Nitrification is usually absent in the uper layers of the bed and moves upwards or downwards depending on the loading. The film in the upper layers

removes most of the organic matter, taxing the oxygenation capacity of the bed at this level. It is not necessary that the oxygen in the air surrounding this layer be appreciably depleted. All that is necessary is that the oxygen consumption should be so great that the rate of oxygen penetration is not rapid enough to meet the demand. In the lower levels, which accumulate smaller quantities of oxidizable organic matter, the situation is reversed and nitrification becomes established. As the load is increased so that an increasing portion of the bed becomes loaded with freshly accumulated organic matter, the zone of nitrification moves downward until the depth is not great enough to allow for a zone of nitrification. Although the phenomenon of failure of nitrification to be established is associated with large accumulation of oxidizable organic matter in the film or the floc, the direct cause of the failure is the limitation of oxygen, brought about by the accumulation of the organic matter. If the rate of oxygen penetration could be increased the two processes would take place simultaneously as was illustrated by the simultaneous nitrification and glucose decomposition in the laboratory experiments where the air supply was ample. Therefore, when nitrates are absent in an oxidation unit, in which the biological flora has had time to establish itself, it is symptomatic of the inability of the oxygenation capacity to cope with the accumulation of oxidizable organic matter. Such a situation may exist when the oxygenation capacity is low or when the load is high. It follows that nitrification gives a good indirect picture of the state of oxidation of the organic matter in the biological film.

The third factor, namely, a limitation of nitrification due to a deficiency of ammonia nitrogen, seldom occurs in biological processes treating domestic sewage. With industrial wastes, containing small quantities of available nitrogen and large quantities of oxidizable organic matter, nitrification and even oxidation of carbonaceous material may be limited by this factor.

Summary

Evidence obtained indicates that oxidation of carbonaceous materials does not inhibit or retard nitrification which can take place simultaneously, provided that:

(*a*) the oxidation of carbonaceous materials does not create a deficiency of oxygen or available nitrogen,
(*b*) there is an active nitrifying flora.

The following observations support this view:

(1) Sewage contains only few nitrifying organisms, so that artificial inoculation with a nitrifying material reduces materially the delay in nitrate production.

(2) The presence of organic matter in sewage does not influence the rate of nitrification of sewage, because on removal of most of the or-

ganic matter by Seitz filtration, nitrification is not hastened. Furthermore, nitrification in seeded sewage proceeds at about the same rate as in a mineral solution.

(3) Artificial aeration of sewage does not materially reduce the time necessary for nitrification in comparison with sewage kept under quiescent conditions in shallow layers. When as little as 100 p.p.m. dextrose is added to sewage, aeration becomes an important factor, because the rate of diffusion and aeration under quiescent conditions is not rapid enough to satisfy the increased oxygen demand. When this oxygen deficiency is eliminated by artificial aeration, the addition of dextrose does not retard nitrification.

(4) When an active nitrifying flora is added to the dilution water in the B.O.D. test of sewage, an additional oxygen demand is exerted from the very beginning, due to nitrification taking place simultaneously with carbon oxidation.

(5) Nitrification proceeds rapidly from the beginning of aeration when activated sludge sewage mixtures are aerated under laboratory conditions.

(6) The addition of sugar to aerating activated sludge exerts a deleterious effect on nitrification only when the nitrogen becomes the limiting factor.

(7) The total oxygen demand exerted in the oxidation of sewage by a nitrifying activated sludge and in the trickling filter is greater than the five-day demand of the sewage by the amount of oxygen required for the oxidation of ammonia nitrogen.

(8) Comparisons of the efficiencies of conventional and high-rate filters based on the five-day B.O.D. values of the effluent are not on an equal basis, because in the former the oxygen demands of carbonaceous as well as a part of the nitrogenous stages are exerted, while in the latter only the carbonaceous stage is included.

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OXIDATION-REDUCTION STUDIES

I. OXIDATION-REDUCTION POTENTIALS DEVELOPED BY PURE CULTURES IN SEWAGE

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Since Potter (1) in 1911 first noted that the electrode potential of an inoculated medium was higher than that of a sterile medium, numerous investigations of the oxidation-reduction phenomena in bacterial cultures have been carried out. The literature on the electropotential effects produced in such bacterial cultures has been the subject of reviews by Hewitt (2), Barron and Stare (3), and Greene and Keilin (4).

The original purpose of this study was to investigate the oxidation-reduction potential changes taking place in the decomposition of organic material contained in sewage and during the oxidation of this material by activated sludge. Clark, Cohen and Gibbs (5) followed, for a period of about four days, the changes in the oxidation-reduction potential of buffered dilutions of sewage. They suggested that this method might be correlated with the putrescibility test of Phelps and Winslow (6).

As the coliform group of bacteria constitute a considerable proportion of the bacterial population of raw sewage, it was decided to study first the E_h changes produced by representatives of this group in sterile domestic sewage and also in synthetic sewage. The study also included observations with a zoogleal bacterium isolated from activated sludge and grown in pure culture by Butterfield (7). On the basis of its cultural, morphological and physiological characteristics, this organism was classified as a variety of *Zooglea ramigera.*

Experimental

The potential measurements were made with a Leeds and Northrup type K-I potentiometer in conjunction with a Leeds and Northrup type P galvanometer having a current sensitivity of .014 milliamperes.

Several different types of platinum electrodes were tried, namely: foil, straight wire and platinum coil. The latter type was finally selected and used in all oxidation-reduction potential measurements. This same type of electrode was used in oxidation-reduction studies carried out by Ward (8), and by Gillespie and Rettger (9). Before being used, the electrodes were cleaned by immersing them alternately in hot dilute nitric acid and sodium bisulfite followed by washing in distilled water. This method of cleaning was found to be quite satisfactory. When not in use, the electrodes were kept immersed in distilled water.

Electrical contact between the electrodes and the potentiometer was made through heavily insulated wire dipping into mercury wells, which in turn were in contact with the platinum electrodes. The circuit was

arranged in such a way that by means of a switch the potential of the different electrodes could be determined in a minimum of time. In a majority of the experiments three electrodes were used and the E_h calculated from the average of the readings.

The saturated calomel half-cell was made up by using electrolytic calomel, redistilled mercury and C. P. potassium chloride. Its potential was taken as 0.246 volts at 25° C. The connection between the half-cell and the potentiometer was arranged so that it was in the circuit regardless of the switch position when an E.M.F. was being measured. The salt bridge of the saturated calomel half-cell dipped into a saturated solution of KCl, which in turn was connected with the electrode vessel by means of a saturated KCl-agar bridge.

A three-necked round bottom liter flask was used as an electrode vessel in this study. The center hole was plugged with a rubber stopper through which passed the three electrodes, a sintered glass diffuser and an outlet tube for the gas to escape. One of the side necks carried a siphon and the other the KCl-agar bridge, both being supported by rubber stoppers. The gas inlet and outlet tubes were plugged with cotton. All exposed surfaces of the rubber stopper were sealed with paraffin just before starting a run. (This is essentially the same electrode set-up as was used by Clifton, Clearey and Beard (10) in their oxidation-reduction studies of *Esch. coli* in peptone culture.)

In those experiments in which anaerobic conditions were maintained, tank nitrogen was passed through an alkaline-pyrogallol tower approximately three feet high, then over reduced copper in a combustion furnace and thence through the electrode vessel. The flow of nitrogen was regulated so as to maintain adequate agitation.

The medium used in these experiments was either filtered domestic sewage or the synthetic sewage developed by Butterfield, Ruchhoft and McNamee (11), both having a 5-day biochemical oxygen demand of about 330 p.p.m. These two media were used alone or fortified with 1000 p.p.m. of glucose.

Preliminary to carrying out an experiment the medium, electrode vessel, siphon, agar bridge and electrodes were sterilized by autoclaving at 15 lbs. pressure for 15 minutes. The electrodes were immersed in distilled water during sterilization. The saturated KCl-agar was also sterilized in 50 ml. portions in test tubes.

Just prior to starting a run the sterile KCl-agar was melted and the agar bridge filled and allowed to solidify. The growth from three 24-hour agar slants of the organism under test was washed off with approximately 5 ml. of sterile dilution water and added to the medium. The latter was shaken to insure uniformity of dispersion. The inoculated medium (approximately 500 ml.) was then added to the electrode vessel, the agar bridge and siphon were inserted in the side necks, the stopper carrying the electrodes together with the gas inlet tube was inserted in the center neck and the whole assembly immersed in a constant temperature bath maintained at $25° \pm 0.1°$ C. As stated previously, the connection between the calomel half-cell, immersed in

the same bath, and the electrode vessel was made through a saturated KCl reservoir into which dipped the agar bridge and arm of the calomel half-cell. The lead wires to the potentiometer were then connected to the electrodes and potentiometric readings of the various electrodes were made. During the active growth stage readings were made at 15 minute intervals. At various times samples were removed aseptically by means of a sterile siphon for bacterial counts, pH and glucose determinations. As it was necessary to keep the sample size small (approximately 10 ml.) the pH determinations were made colorimetrically using an S.D.C. pH kit instead of with the glass electrode.

By using three electrodes in each experiment a better estimation of the potential of the bacterial culture could be made. Sometimes poisoning of an electrode occurred and its potential would be out of line with the other two; in some instances differences as large as 80 mv. were found. As a rule the three electrodes would check within 5.0 mv.

Results

In Table I are given representative results obtained in quiescent cultures of *Bact. coli* and *aerogenes* in sterile sewage with and without a supplemental feed of 1000 p.p.m. of glucose. These results are shown graphically in Fig. 1.

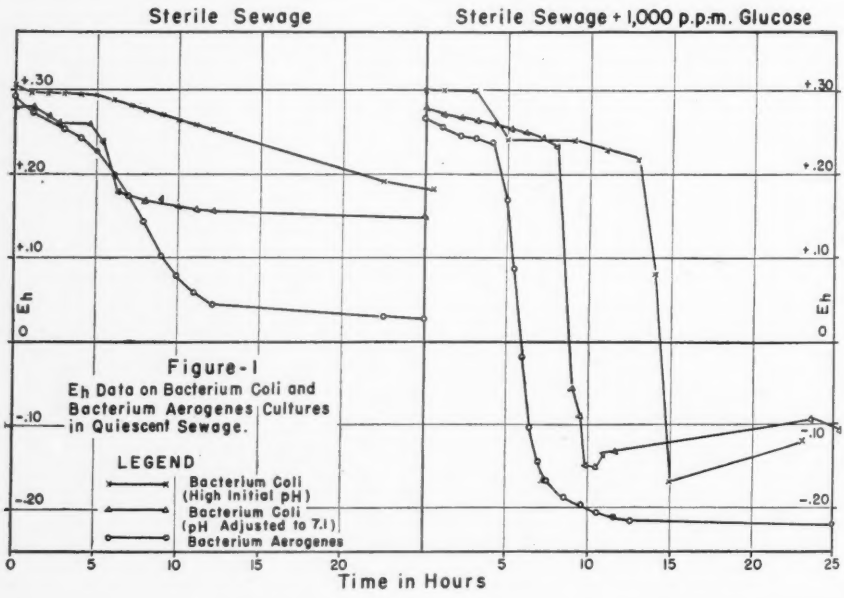


Figure-1
Eh Data on Bacterium Coli and Bacterium Aerogenes Cultures in Quiescent Sewage.

In the case of quiescent cultures, a greater variation in the potential as shown by individual electrodes was noted. This is due, presumably, in part, to the occurrence of stratification in the culture medium which

TABLE I.—*Sewage E_h, Experiments Series I Quiescent Growth in Pure Culture*

Substrate	Sterile Sewage						Sterile Sewage + 1000 p.p.m. Glucose					
Culture	*Bact. coli*		*Bact. coli*		*Bact. aerogenes*		*Bact. coli*		*Bact. coli*		*Bact. aerogenes*	
	Time (1)	E_h (2)	Time	E_h	Time	E_h	Time	E_h	Time	E_h	Time	E_h
	0	+.279	0	+.303	0	+.293	0	+.303	0	+.279	0	+.267
	1	.276	1	.296	1	.275	1	.296	1	.270	1	.256
	2	.273	2	.297	2	.264	3	.297	2	.268	2	.245
	2½	.257	3	.297	3	.256	5	.244	3	.264	3	.241
	3½	.258	4	.294	4	.244	7	.242	4	.261	4	.238
	4½	.256	5	.294	5	.228	8	.240	5	.253	5	.167
	5½	.241	6	.289	6	.200	9	.239	6	.250	5½	.087
	6½	.183	7	.279	7	.176	10	.237	7	.242	6	−.019
	7½	.171	8	.275	8	.145	11	.233	8	.232	6½	.102
	8½	.165	9	.271	9	.101	12	.228	9	−.054	7	.137
	9½	.162	10	.264	10	.080	13	.221	9½	.087	7½	.168
	10½	.164	11	.259	11	.061	14	.078	10	.150	8½	.187
	11½	.165	12	.254	12	.044	14½	−.080	10½	.149	9½	.196
	25	.149	13	.247	13	.041	15	.167	11	.135	10½	.203
			22½	.192	23	.028	15½	.189	11½	.132	11½	.210
			25½	.182	25	.027	23	.117	23½	.092	12½	.215
							26	.122	25½	.100	25	.219
Initial pH	7.1		8.8		7.0		8.4		7.3		7.2	
Final pH	6.9		8.4		6.7		4.3		4.3		4.6	
Bacterial counts (3) in millions per ml. at indicated time	0 (4)	1.54 (3)	0 (4)	1.45 (3)	0 (4)	1.69 (3)	0 (4)	.69 (3)	0 (4)	.81 (3)	0 (4)	3.65 (3)
	3	1.94	3	1.98	3	2.38	3	.85	3	.97	3	4.60
	25	50.	25	25.2	25	82.5	26	255.	26	209.	26	89

(1) Time in hours.
(2) E_h in volts.
(3) Bacterial counts made after 48 hours at 20° C. on plain agar.
(4) Time in hours when bacterial counts were made.

could easily cause a greater divergence in electrode values than if uniform conditions were maintained throughout the culture vessel.

As will be noted in Fig. 1 the potential developed in the aerogenes culture was lower than in the *coli* culture, both in the absence and in the presence of a supplemental feed of glucose. As would be expected, a much lower potential (— .22 volt in the case of aerogenes and — .16 volt in the case of *coli*) was reached when a glucose fortified sewage was used than in the sewage alone (+ .17 and + .24 volt). The effect of a high initial pH is also shown in the case of the coli cultures, where in the absence of glucose, no sharp break in the E_h-time curve appears and at the end of 25 hours the bacterial count had reached only 25 million

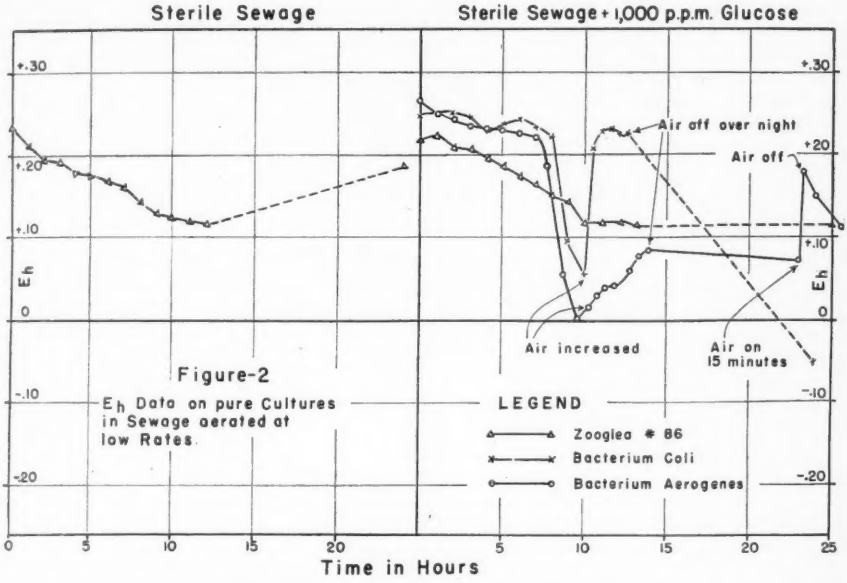
TABLE II.—*Sewage E_h Experiments, Series II, Pure Cultures with Low Rates of Aeration*

Substrate	Sterile Sewage		Sterile Sewage + 1000 p.p.m. Glucose					
Culture	Zooglea No. 86		*Bact. coli*		*Bact. aerogenes*		Zooglea No. 86	
	Time (1)	E_h (2)	Time	E_h	Time	E_h	Time	E_h
	0	+.237	0	+.246	0	+.268	0	+.218
	1	.213	1	.251	1	.251	1	.223
	2	.195	2	.250	2	.242	2	.207
	3	.192	3	.245	2¾	.236	3	.203
	4	.178	4	.228	3¾	.233	4	.195
	5	.173	5	.234	4¾	.230	5	.185
	6	.169	6	.241	5¾	.226	6	.171
	7	.161	7	.231	6¾	.218	7	.163
	8	.143	8	.222	7¾	.186	8	.149
	9	.128	9	.094	8¾	.051	9	.143
	10	.123	10 (4)	.052	9¾	.005	10	.114
	11	.119	10½	.203	10¼ (4)	.017	11	.117
	12	.115	11	.227	10¾	.030	12	.117
	24 (4)	.184	11½	.230	11¼	.037	13	.115
			12	.226	11¾	.037	25	.113
			12½ (5)	.225	12¼	.041		
			24	−.052	12¾	.058		
					13¼	.076		
					13¾ (5)	.083		
					23 (6)	.071		
					23¼ (7)	.181		
					24	.151		
					25¾	.113		
					28½	.097		
Initial pH.....	7.1		6.7		7.1		7.1	
Final pH.....	7.5		4.3		4.8		6.7	
Bacterial counts (3) in millions per ml..	0	156.			0	4.6	0	142
	24	119.			29	400.	25	1,023

(1) Time in hours. (2) E_h in volts. (3) Bacterial counts after 48 hrs. at 20° C. on plain agar.
(4) Air increased. (5) Air turned off overnight. (6) Air on 15 minutes. (7) Air turned off.

per ml., at the same time the pH was lowered only to 8.4. However, when glucose was used as a supplemental feed and with an initial pH of 8.4, the break in the E_h-time curve was delayed approximately 5 hours, but substantially the same negative potential was reached as when the initial pH had been adjusted to 7.1.

The data given in Table II and illustrated graphically in Fig. 2 show the effect of maintaining aerobic conditions upon the oxidation-reduction potential developed in cultures of the three bacteria studied.



As would be expected, the attainment of intense reducing conditions is inhibited by the presence of oxygen. Thus with *coli* in the presence of glucose, the potential does not fall below + 0.05 volt, to about + 0.01 volt with *aerogenes* and to + 0.10 volt with the zoogleal bacterium. When the aeration rate was increased after 10 hours of aeration at a low rate, the E_h is seen to rise sharply in the case of *coli* and more gradually in the case of *aerogenes*. When the air supply was shut off over night, however, a decided negative shift in the E_h of the *coli* culture was found, whereas a very slight negative shift of the *aerogenes* culture occurred. Other experiments carried out with *aerogenes* in synthetic sewage fortified with glucose under the same conditions demonstrated a decided negative drift in the potential (— .12 volt) when aeration was discontinued over night.

Experiments were also carried out with *coli* and with *aerogenes* in which anaerobic conditions were maintained throughout the experiment by bubbling purified nitrogen gas through the electrode vessel. Results of typical experiments are given in Table III. At the same time the change in the oxidation-reduction potential was being followed, the

TABLE III.—*Sewage E_h Experiments—Pure Cultures Agitated with Washed Nitrogen*
(The substrate in all experiments was synthetic sewage plus glucose)

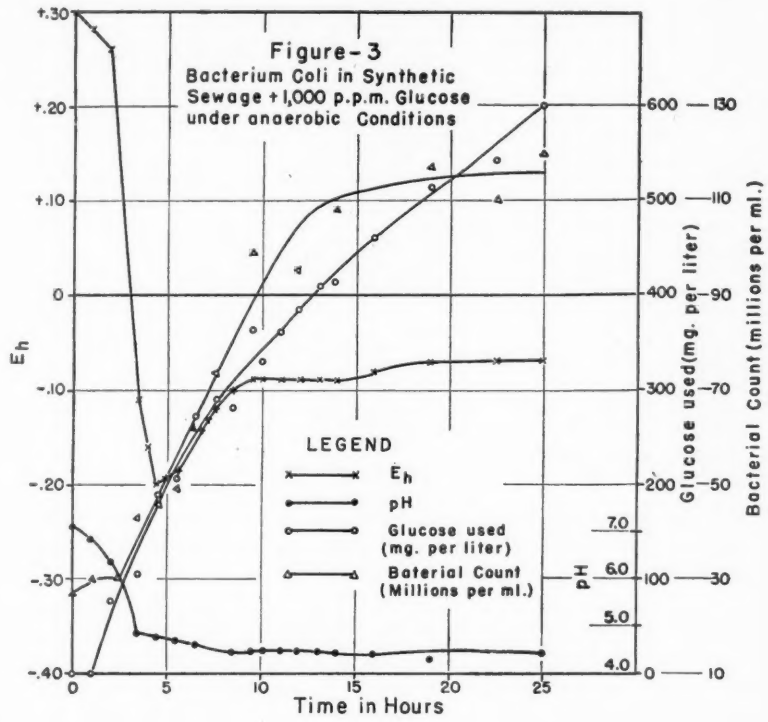
Culture	*Bact. aerogenes*				*Bact. coli*			
Time in Hours	E_h Volts	pH	P.P.M. Glucose Used	Bacterial Count (1)	E_h Volts	pH	P.P.M. Glucose Used	Bacterial Count (1)
0	+.293	7.1	0	38.6	+.306	7.1	—	27.4
1	.277	6.7	37	42.1	.277	6.9	0	29.8
1½	.252	6.7	9	50.8				
2	.241	6.1	28	57.8	.255	6.4	73	30.0
2½	.240	—	—	—	—	—	—	—
3	−.022	4.8	87	45.5	—	—	—	—
3½	.131	4.8	128	54.0	−.108	4.8	103	42.7
4	.199	4.8	168	—	.158	—	—	—
4½	.193	4.8	202	67.5	.202	4.8	190	46.5
5	.197	—	—	—	.194	—	—	—
5½	.198	4.7	244	62.0	.180	4.7	205	48.6
6	.200	—	—	—	—	—	—	—
6½	.194	4.6	292	—	.135	4.6	271	61.5
7	—	—	—	—	.126	—	—	—
7½	.191	4.6	378	—	.115	4.6	286	73.6
8½	.186	4.6	480	69.0	.103	4.5	279	—
9½	—	—	—	—	.093	4.5	363	—
10	.162	4.7	632	81.0	.090	4.5	334	98.6
10½	—	—	—	—	—	—	—	—
11	.124	4.6	875	—	.091	4.5	358	—
11½	—	—	—	—	—	—	—	—
12	.122	4.5	1019	—	.090	4.5	383	95.4
12½	—	—	—	—	—	—	—	—
13	.086	4.5	1034	190.0	.089	4.5	409	—
13½	—	—	—	—	—	—	—	—
14	—	—	—	—	.088	4.4	412	108.0
16	—	—	—	—	.083	4.4	460	97.4
19	—	—	—	—	.071	4.3	516	117.0
22½	—	—	—	—	.076	4.3	545	110.0
23	.016	4.6	1038	179.0	—	—	—	—
25	—	—	—	—	.070	4.4	603	120.0
28	—	—	—	—	.073	4.4	650	100.0

(1) Millions of bacteria per ml. as determined on plain agar after 48 hours at 20° C.

pH, bacterial counts and glucose utilized were determined. The glucose was determined by the Hassid method as adapted to this type of material by Ruchhoft, Kachmar and Moore (12).

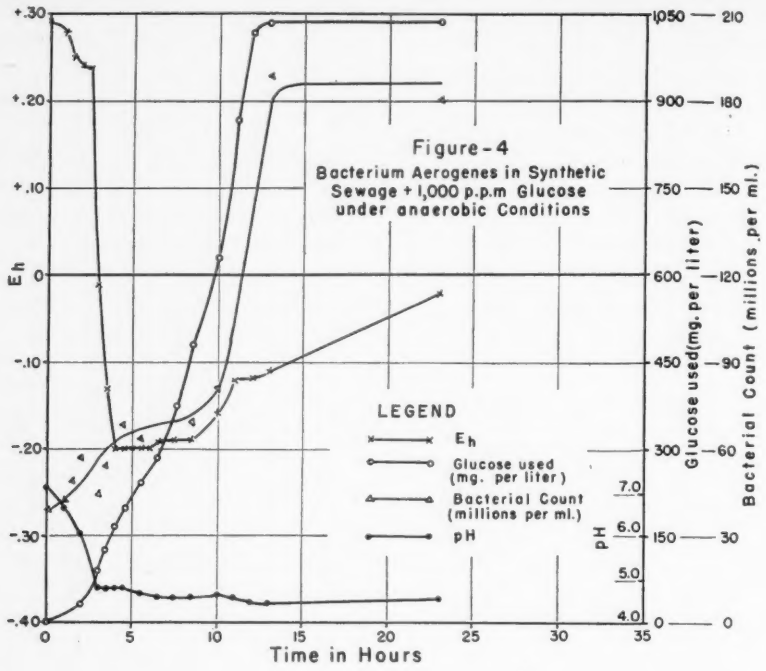
In Fig. 3 the data for the *coli* culture are shown graphically. It is noted that the lag phase of growth corresponds to the initial relatively slow change in potential. However, as soon as the logarithmic growth phase was under way the E_h dropped sharply, the pH also showing an abrupt change. After the minimum potential was reached (— .20 volt) a reversal occurred and a slow positive drift was noted until about the tenth hour when the E_h-time curve flattened out. At approximately the same time the pH time curve becomes asymptotic to the X axis.

After the minimum potential is reached there appears to be some direct correlation between the change in E_h, the growth curve, and the glucose consumed for a short period (about 4 hours). Thereafter the E_h curve becomes almost asymptotic to the X axis, which leads to the inference that the glucose consumed is being used for synthesis of protoplasm with a decrease in the end products of dissimilation. During the last ten hours of this experiment there was apparently a failure in the rate of



division of the bacterial cells but the glucose continued to be removed at about the same rate.

In Fig. 4 the corresponding curves for *aerogenes* are shown graphically. As with the *coli* strains studied, after the initial lag period, the E_h and pH curves dropped abruptly, the E_h fell to a potential of — .2 volt, and the pH showed its greatest change simultaneously. After reaching the minimum potential the E_h remains fairly constant for a period of approximately 4 hours, and then a reversal of potential occurs. The pH, meanwhile, shows comparatively little change. The maximum utilization of glucose per unit of time corresponds to the maximum growth rate of the bacteria, the two curves becoming asymptotic to the X axis at approximately the same time.



Discussion

The study of the growth of bacteria in quiescent culture in which the end products of the bacterial metabolism are allowed to accumulate should give better data on the effect of such metabolic activities upon the E_h than where unnatural conditions are maintained. As pointed out earlier, however, temporary poisoning of an electrode may occur as well as stratification in the electrode vessel, either of which factors may give erroneous E_h values. If one attempts to control conditions by gaseous agitation of the culture or by buffering, then the normal growth conditions are disturbed and further complications are introduced. Likewise, any attempt to correct E_h values for pH fluctuation is very difficult, as the curve relating E_h to pH in bacterial culture has a varying slope, as pointed out by Knight (13) and the effect of altering the H^+ ion concentration is different for different pH ranges as shown by Clark and Cohen (14).

The difficulty of comparing oxidation-reduction potentials developed in quiescent cultures with values obtained by other investigators is apparent when one considers the effect of the composition of the medium upon such potentials. For example, Hewitt (2) reports a value of approximately — 0.35 volt for *Bact. coli* in a one per cent glucose broth culture which is about 0.20 volt lower than found in the present study. It must be remembered, however, that the glucose concentration used in his study was ten times as great and that the tem-

perature was 37° instead of 25° C. Temperature has a much greater bearing upon the growth rate for *coli*, as shown by data given by Buchanan and Fulmer (15), than upon that of *aerogenes*, whose optimum growth temperature lies closer to 30° than to 37° C. In all of the experiments carried out with quiescent cultures a lower potential was developed in those cultures in which glucose was used as a supplemental food. This is understandable on the basis of the end products formed as a result of metabolic activities.

When aerobic conditions were maintained, it was found that in spite of the presence of dissolved oxygen, the three organisms studied were able to set up reducing conditions in the culture. The zoogleal organism has the least effect upon the E_h, as the end products formed are such that the oxidation-reduction potential is not affected appreciably, though approximately 45 per cent of the glucose absorbed is oxidized to CO_2 and H_2O during a 24-hour period, acid end products are not produced. According to Ruehhoft, Kachmar and Placak (16) approximately the same percentages of the glucose absorbed is oxidized by aerogenes as by the zoogleal organism, nevertheless, with the former organism the acid end products formed have an appreciable effect upon the E_h of the medium.

The maintenance of anaerobic conditions by means of nitrogen throughout the growth of the culture has no apparent effect upon the minimum potential developed in cultures of aerogenes and coli. Even though these two organisms show a continued growth and glucose utilization after the minimum potential is reached, a large portion of the glucose absorbed is being used for synthesis of cell protoplasm and only a small portion is dissimulated to other end products. This same phenomenon has been noted in the case of the glucose metabolism of activated sludge (16). After the minimum potentials are reached there is a shifting of the oxidation-reduction system present so that the E_h becomes more positive. With *coli* a stabilized condition results after a shift of approximately .1 volt which is to be expected as this organism is unable to utilize the end products which have been formed and only approximately 50 per cent of the glucose has been removed from the substrate. However, *aerogenes* is able to utilize the end products of its metabolism, all of the glucose is removed from the substrate and one would expect a continued positive drift in E_h.

Summary

Coli and *aerogenes* in quiescent culture are able to effect a lower oxidation-reduction potential in the medium in the presence of glucose than in its absence. More erratic electrode results are obtained in such cultures due to poisoning of the electrodes and to zone effects.

The maintenance of aerobic conditions by passing air through the electrode vessel results in much more positive E_h values being obtained. Nevertheless, it is shown that both *coli* and *aerogenes* are able to effect

reducing conditions in the culture in spite of the presence of an adequate oxygen supply.

When anaerobic conditions are maintained throughout the growth of the culture the sharp drop in E_h corresponds to the abrupt change in pH after the initial lag period. The utilization of glucose continues after the minimum potential is reached but it is being used for synthesis of cell protoplasm. *Aerogenes* is able to utilize the end products and a more positive drift in potential results than in the case of *coli*, which is not able to utilize such products.

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ESTIMATION OF COLIFORM BACTERIA IN RAW AND CHLORINATED SEWAGE BY MEANS OF DIFFERENT MEDIA

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In the control of sewage treatment plants where disinfection by chlorination is an essential process, it is frequently necessary to determine the results accomplished by estimating the number of coliform bacteria that remain in the chlorinated effluent, as well as to determine the coliform organism content of the raw sewage. To obtain this information on coliform bacteria densities in raw and chlorinated sewage, the use of the standard method of complete confirmation of the American Public Health Association (1) is, in the words of Prescott and Winslow (2), ". . . highly time consuming and expensive." That this idea has received considerable attention since that time is evidenced by the work of McCrady (3), Kelly (4), Taylor (5), Ruchhoft (6), and others, working on raw and treated waters to determine a selective medium which would give satisfactory results in a shorter period of time.

Inasmuch as we have been unable to find direct reference to any work done on comparing the results obtained by various media in the testing of sewage, this study was undertaken. Comparative studies on several media and phases of the problem were begun after considering the work of McCrady (3), Kelly (4), and Jordan (8), on the comparison of brilliant green bile lactose broth as a confirmatory medium with other media for the same purpose, and the work of Mallmann and Darby (9), and Cowls (10), on selective media for coliform organisms.

The studies included the following: (1) comparison of eosin methylene blue agar with brilliant green bile lactose broth (2 per cent) as confirmatory media, (2) comparison of presumptive lactose gas formers with confirmation in brilliant green bile lactose broth, (3) comparison of direct planting in brilliant green bile lactose broth, and lauryl sulfate tryptose broth with results determined by confirmation in brilliant green bile lactose broth, and (4) a few tests using violet red bile agar as a direct counting medium.

In the control of the sewage treatment disinfection process at the Buffalo sewage treatment works, the Bird Island Laboratory collects and analyzes, at regular intervals, samples of raw and chlorinated sewage. The decrease in coliform bacteria content and the maintenance of a desired coliform organism limit in the plant effluent are measures of the effectiveness of chlorination. The fact that these regular samples are collected and analyzed, gave excellent opportunity to make these comparative studies using different media for the estimation of the number of coliform organisms present in raw and chlori-

nated sewage. The disinfection results of chlorination at Buffalo have been published elsewhere (7) and it is the purpose of this paper to present the results of these above mentioned comparative studies.

As far as these studies on sewage and chlorinated effluents go, they appear to indicate that if direct planting is used, brilliant green bile lactose broth (2 per cent) is the best selective medium, but for routine control of sewage chlorination processes, the use of the presumptive test with lactose broth, without confirmation, is adequate.

Methods of Study

Throughout the studies, the media used were of the dehydrated variety prepared by the Difco Laboratories. The formulae of the media used for lactose broth, brilliant green bile lactose broth (2 per cent), eosin methylene blue agar, and violet red bile agar, are given in the Difco Manual (11). The formula for lauryl sulfate tryptose broth was furnished by Prof. W. L. Mallmann (12), as follows:

Bacto-tryptose	20 grams per liter	
Bacto-lactose	5 " " "	
Potassium phosphate (primary)	4 " " "	
Potassium phosphate (secondary)	1.59 grams per liter	
Sodium lauryl sulfate	0.7 " " "	(as Duponol paste)
Sodium chloride	5.0 " " "	

In the case of liquid media, the serial dilution method was used for the estimation of coliform bacteria. Three tubes were used for each dilution, and with raw sewage samples, the smallest dilution used was 1/10,000 ml. For the chlorinated effluent, when no residual chlorine was present, dilutions of 1/100, 1/1000, and 1/10,000 ml. were used; when residual chlorine was present, portions of 1/10, 1/100, and 1/1000 ml. were used for planting. Incubation was for 24 or 48 hours as necessary. All results were calculated as most probable numbers (M.P.N.) of coliform bacteria per ml. in accordance with the U. S. Public Health Report tables (13). Chlorinated sample results were used only when the M.P.N. was less than 500 per ml., since higher results indicate less complete disinfection.

Previous work in this laboratory (14) had indicated that lactose tubes planted with raw sewage, when positive at the end of 24 hours, gave confirmation in brilliant green bile lactose broth more than 99.9 per cent of the time. Therefore, it was the practice of these studies not to confirm positive presumptive lactose tubes on raw sewage, at the end of 24 hours. It was assumed on the basis of the previous work that they would confirm and that any error in this assumption was negligible. All 24 hour positive tubes from chlorinated sewage and 48 hour positive tubes from raw and chlorinated sewage were confirmed with B.G.B. lactose broth.

The routine plant control samples were used as the basis of these studies. Samples of the raw sewage and the chlorinated effluent are collected six times between 5:00 A.M. and 4:00 P.M. daily. For each

raw sewage sample collected at any particular hour, a chlorinated effluent sample is taken one hour later. This difference in time approximates the contact period during which disinfection due to chlorination has been in progress. The special studies and analyses were made on samples representing the 10:00 A.M. and 1:00 P.M. sewage before and after chlorination. Samples were analyzed within 10 to 15 minutes after collection, eliminating storage. In the case of the chlorinated samples, any residual chlorine in the sample was neutralized with sodium thiosulfate. These two features of the technique eliminate regrowth from storage (7), and the effect of length of chlorine contact time which, as Manning (15) points out, appreciably affects results.

Experimental Results

Unfortunately, it was not possible to run comparative studies on all of the media, for the entire period of time. Therefore the results are tabulated in such a way that only those tests which were made on the same samples are actually compared. In each series of tests, the comparisons are made to the results obtained by confirmation in B.G.B. lactose broth. In every case it is assumed that the results obtained by confirmation in the B.G.B. broth represent the actual most probable number of coliform organisms present, because confirmation in B.G.B. broth gives results as accurate as the Standard Methods completed test (4).

Table I shows the results of a comparison of confirmation on the E.M.B. agar with confirmation in B.G.B. lactose broth.

Table I.—*Comparison of B.G.B. Broth with E.M.B. Agar as a Confirmatory Medium. M.P.N. Coliform Bacteria Per ml. (39 Observations)*

Sample	M.P.N. Presumptive Coliform Bacteria	M.P.N. by Confirmation		Ratio of M.P.N. by Confirmation to Positive Presumptive M.P.N.	
	Lactose Positive	B.G.B. Broth 2%	E.M.B. Agar	B.G.B. Broth	E.M.B. Agar
Raw Sewage.....	60,900	50,100	37,500	86%	72%
Chlorinated Settled Sewage.....	76.2	40.5	19.9	53%	26%

Three observations are to be made from the data in this table. First, that B.G.B. lactose broth gives a higher percentage confirmation of gas formers than does the E.M.B. agar. Secondly, in the case of chlorinated sewage, the confirmation in the B.G.B. lactose broth is twice as much as on E.M.B. agar, whereas in the case of raw sewage, the confirmation in B.G.B. lactose broth is only 1.2 times as much as on the E.M.B. agar. Thirdly, it appears that the ratio of M.P.N. by confirmation to M.P.N. calculated from positive gas formers in raw sewage is considerably greater than a similar ratio in chlorinated sewage.

Inasmuch as these results represent only 39 observations, they are not in themselves conclusive. They do indicate, however, that results obtained with these confirmatory media in raw and chlorinated sewage are similar to those obtained in raw and treated water.

The results of the tests comparing direct planting in B.G.B. lactose broth, with confirmation in B.G.B. lactose broth, are shown in Table II.

TABLE II.—*Comparison of Direct Planting in B.G.B. Broth (2%) with Lactose Presumptive Gas Formers and Confirmation in B.G.B. Broth. M.P.N. Coliform Bacteria/ml.*

Sample	Number of Observations	Positive Presumpt. Gas Formers	Confirmed B.G.B. Broth 2%	Direct Plant. B.G.B. Broth	Ratio of M.P.N. to Presumptive M.P.N.		Ratio M.P.N. by Direct Planting to M.P.N. by Confirmation
					Confirmation	Direct Planting	
Raw Sewage	621	73,000	68,500	60,100	93.8%	82.3%	88%
Chlorinated Settled Sewage	478	84.0	42.3	31.8	50.4%	37.8%	75%

These data cover a rather large number of tests and, therefore, should be fairly indicative of the results that may be obtained by these different methods.

From the data in this table, it may be observed that in the case of raw sewage nearly 94 per cent of the most probable number of presumptive coliform bacteria confirm. This is a slightly higher value than obtained in the fewer observations listed in Table I. In the case of chlorinated sewage, the ratio of confirmed M.P.N. to presumptive M.P.N. is slightly over 50 per cent. This is approximately the same ratio as shown by the fewer observations in Table I. On the assumed basis that the confirmed results in B.G.B. lactose broth represent the actual numbers of coliform organisms present, direct planting in B.G.B. lactose broth gives low results for coliform bacteria density. It is also observed in the case of chlorinated sewage, that direct planting in B.G.B. lactose broth gives results somewhat lower by comparison to confirmation data than in the case of raw sewage. Inasmuch as we were interested in the possibility of using presumptive gas formers as a basis of determining disinfection efficiency, Table II also shows the relation of the presumptive coliform bacteria to the confirmed results. In the case of raw sewage, positive presumptive gas formers would give a most probable number slightly high, but in the case of chlorinated sewage, the presumptive results would be almost double those obtained by confirmation technique.

From Table II it appears then that if the per cent kill of organisms is used as an index of disinfection efficiency, direct planting in B.G.B. lactose broth gives a very slightly higher efficiency, whereas data on presumptive gas formers give somewhat lower bacterial kill, although all results in percentage kill would be of the same general order. This

observation indicates that perhaps the number of residual coliform bacteria after chlorination, rather than the per cent kill, should be a measure of effectiveness of disinfection.

Studies on lauryl sulfate tryptose broth as a direct planting medium were carried on for a part of the study. At the same time direct planting in B.G.B. lactose broth was used and the results of both were compared to confirmation of lactose broth gas formers in B.G.B. lactose broth. The data on these experiments are shown in Table III.

TABLE III.—*Comparison of Direct Planting in L.S.T. Broth and in B.G.B. Broth with Confirmed Results. M.P.N. Coliform Bacteria/ml.*

Sample	Number of Observations	Confirmed in B.G.B. Broth	Direct Planting	
			B.G.B. Broth	L.S.T. Broth
Raw Sewage.....	229	38,000	38,600	29,000
Chlorinated and Settled Sewage.....	153	81.3	68.8	58.7

It is of interest to note from these data on raw sewage that direct planting in B.G.B. lactose broth gave almost identical most probable number results with the confirmations of presumptive tests in the 229 observations made, whereas lauryl sulfate tryptose broth gave results of about 75 per cent of the confirmed results. As in the case of the larger number of observations (Table II), direct planting in B.G.B. lactose broth when compared to the confirmation data, gave lower results in chlorinated sewage than in the case of raw sewage. In the case of chlorinated sewage, however, use of lauryl sulfate tryptose broth gave M.P.N. results bearing approximately the same relation to M.P.N. by confirmation in B.G.B. lactose broth as did the results in raw sewage. Although the results obtained by the use of lauryl sulfate tryptose broth as a direct planting medium gave values lower than confirmation tests, it was observed that a more luxuriant growth of bacteria appeared in a shorter time in the lauryl sulfate tryptose medium than in the other media used. It was also observed that fewer tubes became positive between 24 and 48 hours incubation, than in the case of the presumptive lactose broth tubes or direct planting in B.G.B. lactose broth.

In the case of the raw sewage data, wherein the results of direct planting in B.G.B. lactose broth gave practically identical numbers with confirmation (Table III), it should be observed that the number of coliform organisms present was about half of the average for the entire period of study (Table II). These tests (Table III) were run largely in the winter months when the concentration of coliform bacteria is lower. The data appear to indicate that at the lower temperatures the two methods (direct planting in B.G.B. lactose broth and confirmation in B.G.B. broth) give practically identical results. A study of the data by months does not bear out this conclusion. The agreement more than likely indicates that the two methods are, within limits for all practical purposes, relatively equal as far as results are concerned.

To study trends with temperature, if any, and to observe variations that occur in data on comparative results, the data were tabulated by months as shown in Table IV.

TABLE IV.—*Monthly Average Coliform Results Determined in Liquid Media. M.P.N. Coliform Bacteria/ml.*

Month	Raw Sewage			Chlorinated and Settled Sewage		
	Presumpt. Gas Form.	Confirm. B.G.B. Broth (2%)	Direct Plant. B.G.B. Broth (2%)	Presumpt. Gas Form.	Confirm. B.G.B. Broth (2%)	Direct Plant. B.G.B. Broth (2%)
July	102,000	95,900	104,700	82.5	64.2	33.4
Aug.	133,800	127,100	126,900	48.9	16.5	7.9
Sept.	126,800	123,300	87,500	55.6	9.2	5.1
Oct.	94,300	81,500	73,400	61.1	13.4	4.5
Nov.	53,400	47,800	57,200	31.0	8.6	9.9
Dec.	37,300	35,700	28,600	88.6	52.2	60.2
Jan.	36,400	39,300	33,200	122.4	62.0	52.8
Feb.	38,400	38,400	27,700	155.6	98.4	72.3
Mar.	39,200	38,000	29,000	201.9	129.0	105.9
Avg.	74,600	70,100	62,100	87.7	45.0	35.5

The data in Table IV cover the same observations as shown in Table II and the averages are approximately the same. In the case of raw sewage, it would appear that for practical purposes the lactose presumptive gas former test, although producing most probable number results slightly higher than the confirmation tests, would be sufficiently accurate for estimating coliform organisms in sewages of high coliform density, whereas direct planting in B.G.B. lactose broth gives results slightly lower. Variations in agreement between the various methods are apparent as might be expected. Perhaps, the lower density obtained by direct planting in B.G.B. lactose broth may indicate that less viable forms of the coliform group find the selective agent to be toxic unless preliminary planting in lactose broth is used.

Comparative results are somewhat different with chlorinated sewage, where direct planting data are relatively the same as confirmation results, but where presumptive gas formers are almost twice confirmation results. Borman, Robinton, and Stewart (16) have stated that, "it does not seem probable that slower lactose fermentation in presumptive tests could be due to degradation of lactose splitting power as the result of treatment and other unfavorable features of environment," because they have "never observed such rapid rejuvenation of cultures actually known to be degraded." It appears from these studies on chlorinated sewage that chlorination has either degraded the coliform organism or in some manner affected its viability. Either that or chlorination has not affected gas forming anaerobes to the extent that it has affected coliform organisms. Note that the positive presumptive M.P.N. are nearly twice the number obtained by confirmations and more than twice those results obtained by direct plant-

ing in B.G.B. lactose broth. These data are similar to those of Levine (17) on the slight value of the presumptive test in chlorinated waters. Is it possible that coliform organisms are so affected that when placed directly in B.G.B. lactose broth the presence of the selective agent (bile and brilliant green dye) prevents their growth? On the other hand, if these organisms are placed in lactose broth, is the bacteriostatic action of the chlorine dissipated by dilution with the result that the organisms will grow? Further inspection of the monthly data and of all tests, including those on direct planting with both B.G.B. lactose broth and lauryl sulfate tryptose broth indicates some variation in the results. The variations may not necessarily point to the errors in the use of the methods or media, but to the number of tubes used for each dilution, for Dalla Valle (18) indicates that unless 20 or more tubes are used in each dilution, the M.P.N. results obtained will not be very accurate.

A study of the individual monthly data on the lauryl sulfate tryptose broth indicates that the results obtained by its use apparently have no relation to the temperature of the sewage examined. From these few observations, it would appear that in this case, at least, the use of lauryl sulfate tryptose broth, as a direct planting medium does not give M.P.N. results as high as those obtained by confirmation in B.G.B. lactose broth of positive lactose tubes.

TABLE V.—*Comparison of Direct Planting in Violet Red Bile Agar with Results in Liquid Media. M.P.N. Coliform Organisms/ml.*

Sample	Number of Observations	Positive Lactose Gas Formers	Confirmed B.G.B. Broth	Direct Planting B.G.B. Broth	Direct Planting Violet Red Bile Agar
Raw Sewage.....	21	93,000	76,700	63,600	8,200
Chlorinated and Settled Sewage....	20	34.7	18.9	2.9	1.3

A few samples were planted in violet red bile agar and these were compared with planting in liquid media. The results for these tests are shown in Table V. Although very few tests were made, the indications were that direct counting on violet red bile agar did not give results of even the same relative magnitude of those obtained by the use of liquid media.

SUMMARY AND CONCLUSIONS

On the basis of the observations in these studies on different media and methods for determining the coliform bacteria density of raw sewage and chlorinated sewage effluents, certain indications may be drawn, as follows:

1. Confirmations of positive gas former presumptive tests are obtained more often in B.G.B. lactose broth than on E.M.B. agar plates, both in raw sewage and chlorinated effluents.

2. The ratio of most probable number results by confirmation of positive lactose gas formers to M.P.N. presumptive coliform organisms differs in raw sewage from chlorinated effluents, regardless of the method of confirmation used. In raw sewage, the M.P.N. by confirmation in B.G.B. lactose is approximately 94 per cent of the M.P.N. of presumptive coliform bacteria; in chlorinated sewage, confirmation results are about half the presumptive M.P.N. results.

3. The use of direct planting in B.G.B. lactose broth gives low M.P.N. results, both in raw sewage and in chlorinated effluents; results in chlorinated sewage are lower in relation to confirmation results than those in raw sewage.

4. The use of lauryl sulfate tryptose broth as a direct planting medium gives M.P.N. results lower than direct planting in B.G.B. lactose broth and lower than results from confirmation in B.G.B. lactose broth, both in raw sewage and in chlorinated effluents.

5. On the basis of these studies, it does not appear that there is any relation between the temperature of the sewage and the results obtained by the different media, although there is a relation between temperature of sewage and number of coliform organisms present.

6. From the standpoint of control of sewage treatment plant operation, where disinfection is employed, it appears that adequate information on the results of disinfection can be obtained by using the presumptive gas former test in lactose broth, particularly in the case of raw sewage where the concentration of coliform organisms is high; also in the case of chlorinated sewage, if chlorination has been complete and the kill is sufficient to reduce the number of coliform bacteria below 500 per ml. If more accurate results are desired in the case of chlorinated effluents, confirmation in B.G.B. lactose broth appears to be preferable to direct planting in B.G.B. lactose broth or lauryl sulfate tryptose broth.

Acknowledgment

The authors desire to acknowledge suggestions from Dr. John F. Norton and from Prof. W. L. Mallmann, who also furnished the material for preparing the lauryl sulfate tryptose broth.

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THE SELECTION OF A DILUTION WATER FOR THE DETERMINATION OF THE B.O.D. OF INDUSTRIAL WASTES

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The current popularity of the B.O.D. test for determining the pollutional strength of wastes may be ascribed largely to the satisfactory results, which in general, have been obtained with its use on normal domestic sewages, in the period since the use of standard bicarbonate and phosphate waters has been recommended. There has also been an intense desire to obtain a means of measuring the pollutional strength of industrial wastes capable of being biologically oxidized. The application to industrial wastes of the dilution-excess-oxygen-method of measuring B.O.D., as developed for use on normal domestic wastes, has been the source of many discrepancies in results and the cause of many an argument and discussion to explain the variations encountered.

It is the opinion of the authors that we are today in about the same position with respect to the determination of the B.O.D. of industrial wastes as was the situation in 1925 in regard to domestic wastes. At that time a sample of sewage submitted to several laboratories for analysis would often yield widely different results. As a result of the work of Theriault, McNamee, and Butterfield (1) at the U. S. Public Health Service Laboratories in Cincinnati, Mohlman, Edwards, and Swope (2) at Chicago, and Heukelekian and Chamberlain (3) at New Jersey, it was established that aged tap or natural river waters gave much higher but more inconsistent results than were obtained with distilled water. It was found that distilled water gave lower results than distilled waters buffered with sodium bicarbonate or phosphates and the results with the buffered waters were in general lower than those obtained with natural waters. Because of the ease of reproducing a buffered distilled water, its use was highly recommended by most investigators. In 1932, the Joint B.O.D. Committee of the Great Lakes and Ohio River Boards of Public Health Engineers reported the conclusions (4) based on their investigations of a "standard" dilution water. They recognized that tap or natural waters would not give reproducible results and recommended the use of a standard dilution water prepared from distilled water containing 300 p.p.m. of sodium bicarbonate as buffer. They also suggested that the use of a phosphate-buffered distilled water at somewhat lower pH values might be more representative of natural conditions and should be studied further.

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The 8th Edition (1936) of *Standard Methods* (5) recommended the use of either bicarbonate or phosphate water as "standard."

Even at this late date and stage of development of the B.O.D. test, samples of many industrial wastes when submitted for analysis to several different laboratories will often yield as many different and sometimes widely differing results. Eldridge (6), as late as 1938, questioned the value of the test for certain industrial wastes.

In spite of the lack of information and knowledge concerning the application of the test to industrial wastes, there have been during the past ten years several investigations reported in the literature which have attempted to establish the fundamentals involved. The first of these was a report by Eldridge (7) concerning the importance of bacterial seed and the second by Holderby and Lea (8) suggesting the importance of the carbon to nitrogen ratio of the waste. In retrospect, it is perhaps unfortunate that both parties used such crude material as sewage to prove their points. Later studies have shown that washed cultures of bacteria as seed, or the addition of pure compounds of nitrogen, have failed to check the results obtained when sewage was used. On the other hand, these preliminary studies have served to stimulate research to uncover what are today believed to be the fundamentals underlying the determination.

In 1935, Lea and Nichols (9) reported on a series of experiments which they had performed to determine the effect on the B.O.D. of pure glucose and of industrial wastes of several different mineral elements, that bacteriologists had come to recognize as important in the nutrition and propagation of bacterial cultures. The results of their investigations showed the desirability of adding such mineral elements as N, P, S, K, Mg, and Ca to the dilution water when wastes deficient in these elements were being examined. The suggestion of adding ammonia nitrogen to the dilution water was in direct contradiction to the strict standards concerning the limits of this element which had previously been considered allowable, and this suggestion met with considerable opposition. Further work by Lea and Nichols (10) substantiated their original contention, and they also presented data to show that the average river water in their native state of Wisconsin contained greater concentrations of phosphorus and nitrogen than they were proposing to add. It is interesting to note that, of the many investigators who have studied the effect of natural waters for dilution purposes, Lea and Nichols were, apparently, the first to present information on the content of phosphorus and its significance.

During the last few years, considerable information has been added to help enlighten us on the general problem. The report of Warrick, Martin, *et al.* (11) concerning an investigation of the pollution of the Fox and East Rivers and Green Bay in Wisconsin has shown that, although slightly lower, the results obtained with Lea and Nichols fortified bicarbonate water were similar to those obtained with river waters. A further report by Martin and Miller (12) has shown several interest-

ing characteristics, some of which are in opposition to current opinion and some of which confirm previous findings. Their discovery that Green Bay water was a less desirable dilution water than Fox River water because of the absence of soluble phosphorus confirms the importance of that element. The suggestion of using water from the receiving stream or body of water is a reversion to old suggestions and will not aid in standardizing the procedure so that results from one laboratory can be compared with those from another. The results reported with various seedings is rather disturbing and will bear further study.

One of the major premises upon which the dilution technique of B.O.D. determination is based is that the degree of oxidation reached at any given time is independent of the original amount of oxidizible matter present. In other words, the amount of oxygen consumed is proportional to the quantity of food originally present. It has been demonstrated that such is the case for domestic sewages within the limits imposed by the solubility of dissolved oxygen and the nature of the test, provided the incubation period is not of too short duration. Those who have used the supplemented dilution water as first proposed by Lea and Nichols (9) in the determination of the B.O.D. of certain industrial wastes have found that the above relationships are not always attained. This deficiency was, undoubtedly, first discovered by Lea and Nichols themselves. They found that the B.O.D. of certain wastes, paper and pulp mill in particular, decreased as the size of the sample used for analysis increased. Such results have often been referred to as "sliding" B.O.D.s. For instance, 1, 2, and 3 per cent mixtures of the same waste might yield B.O.D. values of 250, 200, and 175 p.p.m. or analogous results.

Lea (13, 14) has recently reported on his studies to overcome the "sliding effect" (decreased B.O.D. with decreased dilution) obtained when wastes deficient in nitrogen and phosphorus were involved. His results have shown that the original formula proposed by Lea and Nichols was deficient in phosphorus, and that by increasing the amount of this mineral, oxygen consumptions (B.O.D.) in proportion to the size of sample were obtained. This was found to be the case for solutions of glucose, glycine, and sodium stearate individualy. Furthermore, it was shown that the 5-day B.O.D. of these substances at 20° C., even though the amount of seeding in the beginning was small, with the revised formula approximated 63 to 70 per cent of the total B.O.D. as determined by calculation. In view of these latest findings of Lea, we can speculate only as to what the results obtained by Martin and Miller (12) might have been with fortified water had they used a higher concentration of phosphorus.

The object of the present research was to find some means of establishing which of the proposed formulae for dilution waters is most suitable for determining the B.O.D. of an industrial waste. To accomplish this purpose, the authors decided to follow and extend a technique used by the senior author (15) utilizing domestic sewage. It has often been stated that "domestic sewage has everything," *i.e.*

mineral elements, growth factors and seed. If so, it should provide a most suitable medium in which small quantities of an industrial waste can be placed and then, if the B.O.D. of the waste obtained in the presence of sewage corresponds to that obtained when the waste is mixed with dilution water only, it can be concluded that the dilution water used is of a suitable character. The question of seeding has also received attention.

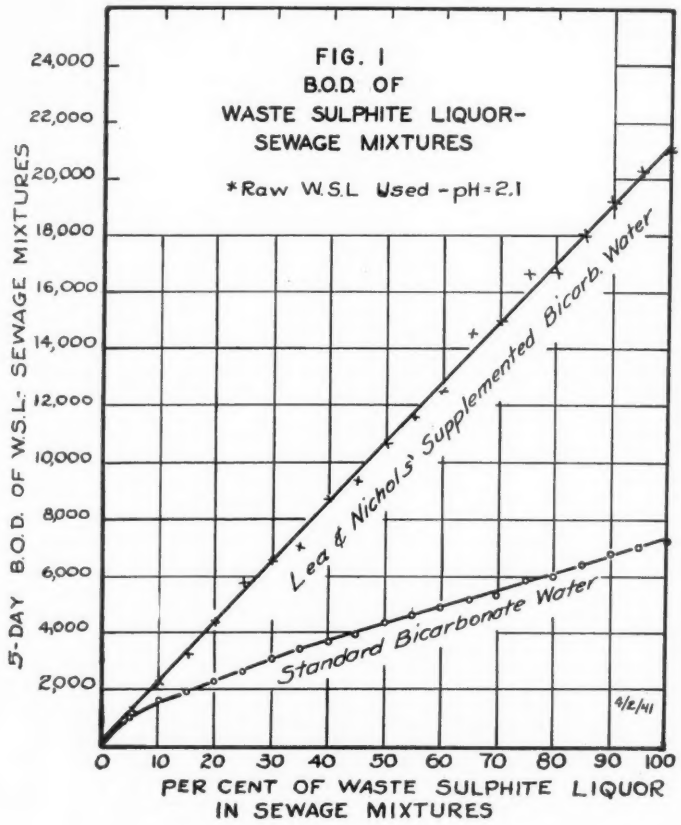

FIG. 1.

Since the start of the experimental work herewith reported, Ruchhoft's Report on the Cooperative Study of Dilution Waters made for the Standard Methods Committee of the Federation of Sewage Works Associations has appeared in print (16). The findings of the Committee were that ammonia nitrogen was a necessary part of a dilution water along with other minerals and did not increase the 5-day B.O.D. of normal sewages and treatment plant effluents. It is unfortunate that the work of the Committee did not involve more industrial wastes, but it is good to have the information confirmed that a mineral supple-

mented water which promises to yield much more uniform results with industrial wastes can also be used with satisfactory results on domestic sewage and treatment plant effluents.

Method

Waste sulfite liquor, a waste which is notoriously deficient in nitrogen and phosphorus in relation to its high carbonaceous content, was selected as a material for testing the various dilution waters to deter-

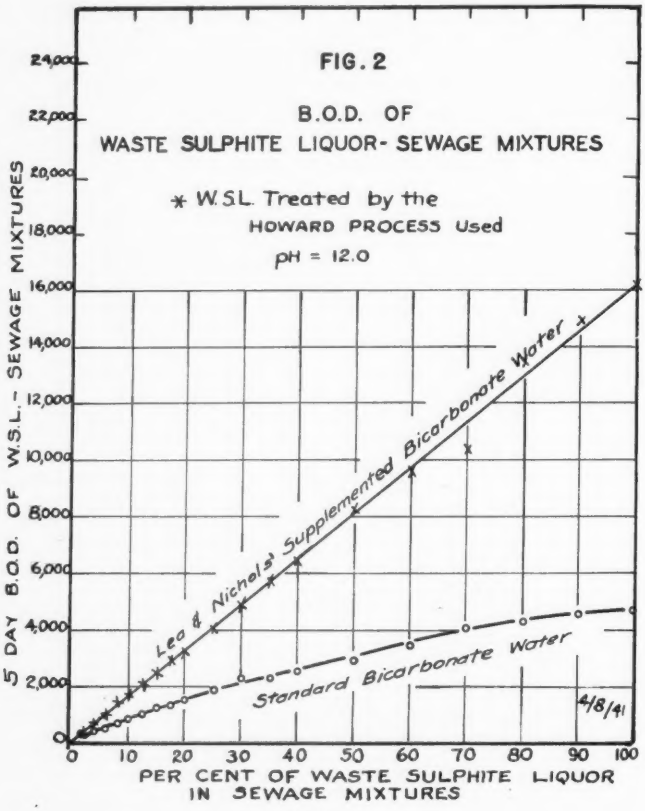

Fig. 2.

mine their suitability for B.O.D. analysis. In addition to its mineral deficiencies, sulfite liquor is practically sterile and has exceptionally good keeping qualities, a characteristic which is important when extended studies are contemplated. The wastes used in the present studies were supplied through the courtesy of the Brown Company of Berlin, N. H., and consisted of undiluted blow-pit liquor. Two supplies were obtained during the course of the experiments. Sewage was obtained from three different sources, Wards Island, Dyckman Street Screening Plant, and Burnside Avenue sewer.

For comparison of the various dilution waters, mixtures of sewage were made with waste sulfite liquor ranging from 100 per cent sewage to 100 per cent of industrial waste. Because of the great variation in the B.O.D. of the various mixtures, preliminary dilutions of all mixtures having values in excess of 300 p.p.m. were made with distilled water to reduce the B.O.D. to within the range from 200 to 300 p.p.m. This allowed uniform sized samples, 3, 5, and 10 ml., to be pipetted directly into

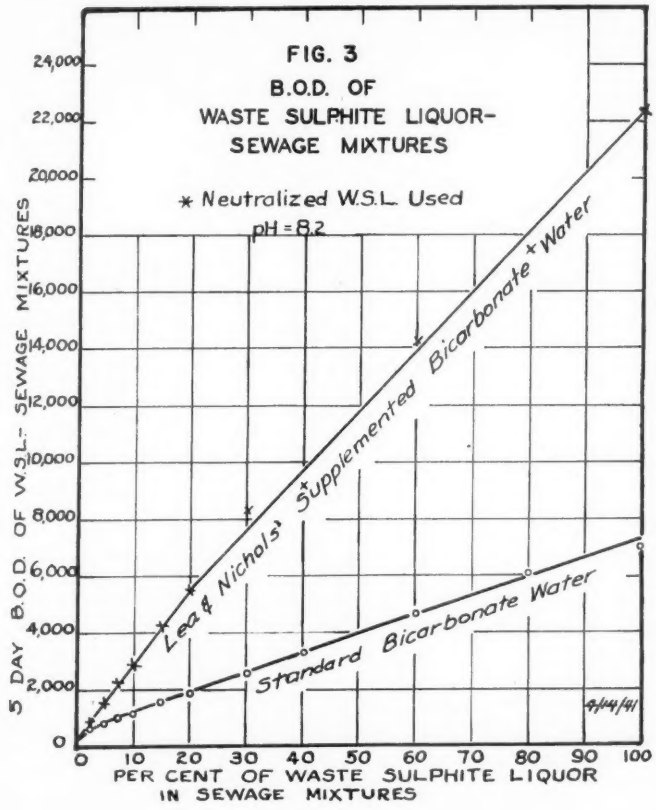

FIG. 3.

the B.O.D. bottles which had been calibrated to the nearest milliliter and which varied in volume from 252 to 257 ml. Studies were made on raw, neutralized, and lime-treated waste sulfite liquor using standard bicarbonate and bicarbonate water supplemented with mineral salts according to Lea and Nichols, as modified by Lea (13, 14). For the remainder of the experiments, neutralized sulfite liquor was used entirely and comparisons of B.O.D. were made using Standard Phosphate Water, Formula C Water, and Formula C water supplemented with nitrogen. Aged distilled water with a copper content less than 0.02 p.p.m. was used for the preparation of all dilution waters and no seed was added. The

TABLE I.—*B.O.D. of Waste Sulfite Liquor-Sewage Mixtures Showing the Influence of Size of Sample and Nature of the Dilution Water*

Per Cent W.S.L. in Sewage Mix	Vol. of *Sample	Bicarbonate Water		Supplemented Water	
		Depletion of D.O. in p.p.m.	B.O.D. in p.p.m.	Depletion of D.O. in p.p.m.	B.O.D. in p.p.m.
Sewage	3 ml.	1.67	141	1.65	139
	5 "	2.87	145	3.02	152
	10 "	5.91	150	5.95	150
2.5	3 ml.	1.68	143	1.92	163
	5 "	2.44	125	3.37	172
	10 "	4.28	109	6.76	172
5.0	3 ml.	1.68	143	2.72	232
	5 "	2.35	120	4.56	233
	10 "	4.08	104	>8.10	—
7.5	3 ml.	1.43	122	2.61	222
	5 "	2.03	104	4.39	224
	10 "	3.38	86	>8.10	—
10.0	3 ml.	1.44	123	3.10	265
	5 "	2.07	106	6.30	272
	10 "	3.36	86	>8.10	—
15.0	3 ml.	1.43	122	2.92	248
	5 "	1.85	95	5.07	259
	10 "	2.83	72	>8.10	—
20.0	3 ml.	1.39	118	3.25	276
	5 "	1.85	95	5.38	274
	10 "	2.87	73	>8.10	—
30.0	3 ml.	1.16	136	2.42	206
	5 "	1.53	78	4.90	250
	10 "	2.36	60	>8.10	—
40.0	3 ml.	1.13	96	2.60	222
	5 "	1.62	83	4.25	218
	10 "	2.32	59	>8.10	—
60.0	3 ml.	1.12	95	2.47	209
	5 "	1.46	74	4.82	248
	10 "	2.23	57	>8.10	—
80.0	3 ml.	1.08	91	2.38	202
	5 "	1.43	73	4.24	218
	10 "	2.10	54	>8.10	—
W.S.L.	5 ml.	1.41	71	4.37	222
	5 "	1.38	70	4.42	224
	10 "	2.20	56	7.92	200

* Waste sulfite liquor-sewage mixtures were diluted to produce B.O.D. values of from 200 to 300 p.p.m. to allow samples of uniform size to be taken for the incubation test.

bottles containing the distilled water were, however, stored unstoppered during the ageing period.

The temperature of incubation was maintained at as near 20° C. as our facilities allowed, and all bottles for a given comparison were kept in the same compartment of the incubator for the 5-day period. The dissolved oxygen determinations after incubation were made by the Wink-

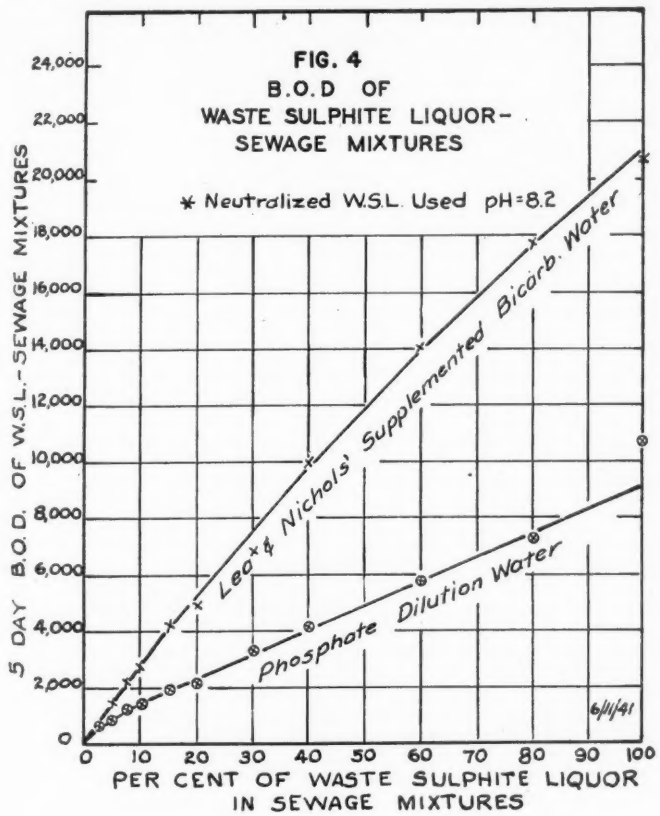

FIG. 4.

ler Method using 2 ml. portions of each reagent. This has been shown by one of the authors (15) and by Martin and Miller (12) to be a satisfactory procedure.

RESULTS

Preliminary investigations were made with raw, neutralized, and lime-treated waste sulfite liquor to determine the effect, if any, of a variation in pH of the waste on the results. Sewage mixtures were studied in all cases and a comparison of the B.O.D. was made using Lea and Nichols modified supplemented bicarbonate water and standard bicarbonate water. The results obtained are shown in Figs. 1, 2, and 3.

The low pH of the raw waste or the high pH of the lime-treated waste seems to have been without effect. Apparently the dilution required was great enough so that the buffering action of the dilution water overcame any residual acidity or alkalinity in the samples.

The B.O.D. results obtained with the two different waters in all cases are in marked disagreement except in those sewage mixtures containing very low percentages of waste sulfite liquor. Undoubtedly the sewage

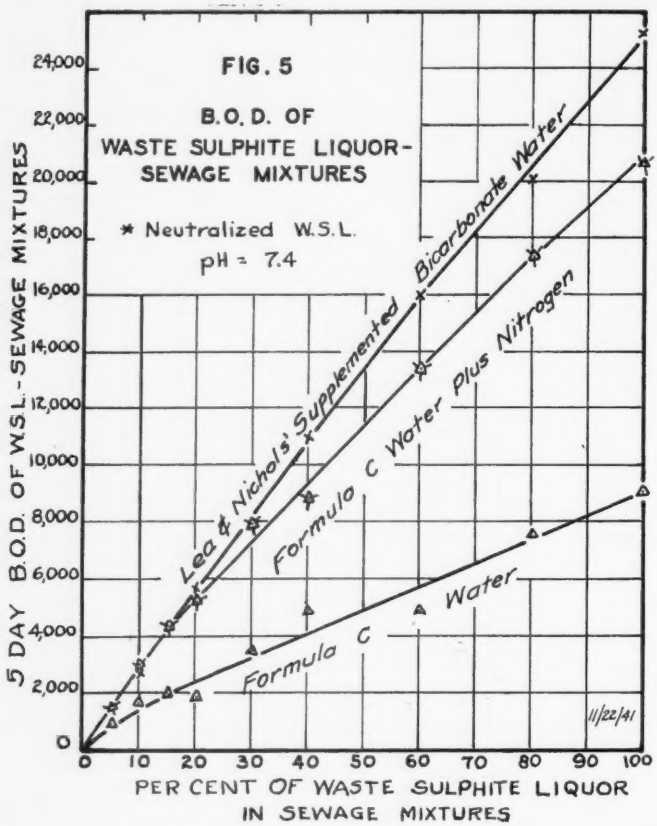

FIG. 5.

provided the necessary minerals for normal biological development in those cases. The nearly straight line relationships obtained with the supplemented bicarbonate water shows definitely that the biological stabilization of sulfite liquor progressed normally in the presence of this water even though the amount of sewage and sewage seed decreased to zero in the case of the sample containing 100 per cent of waste. The fact that the results obtained with the pure waste are in line with those obtained with the sewage mixtures are most interesting. All reasonable precautions were taken to prevent cross contamination, and as far as

we know, only organisms picked up from the air during ageing and aeration of the dilution water (by suction to an aspirator pump) were present in the B.O.D. bottles containing 100 per cent waste. In any event, the seeding was identical in the bottles used for the standard bicarbonate series and the supplemented series.

The lesson that can be learned from these experiments would not be complete without presentation of the data obtained on the various dilutions of each sample using the two different dilution waters. The results obtained with neutralized waste sulfite liquor-sewage mixtures are typical of all and are shown in Table I. From these data it will be observed that the amount of oxygen used was proportional to the size of sample used, or the stage of oxidation reached in 5 days time with the supplemented water was practically the same for each dilution of a given sample. This is shown by the check B.O.D. results which were based on the oxygen depletions. In the case of the results with standard bicarbonate water, we have an excellent example of "sliding" B.O.D.s which indicate that the state of oxidation differed widely for the different dilutions at the end of the incubation period. The futility of averaging such results to obtain a B.O.D. value, as was done in our case to obtain the experimental points for the curves shown in Fig. 3 for standard bicarbonate water, needs further comment. Three distinct curves could have been drawn, one based on the 3 ml. samples, one on the 5 ml. samples, and one on the 10 ml. samples. With such a water, the dilution used for analysis may be all important and the results may be far from 70 per cent of the total demand we expect to obtain in 5 days time at 20° C.

The next step in the experimental work involved a comparison of the supplemented bicarbonate water with phosphate dilution water. The results are given in Fig. 4 and show that phosphate water was only slightly superior to bicarbonate water (Fig. 3) if at all. The results

TABLE II.—*Showing the Method of Calculating the B.O.D. of Waste Sulfite Liquor from the B.O.D. of Waste Sulfite Liquor-Sewage Mixtures*

Per Cent W.S.L. in Sewage Mixture	B.O.D. in p.p.m.		Correction for Sewage	B.O.D. due to W.S.L.		Factor	Calculated B.O.D. of W.S.L.	
	Bicarb. Water	Supp. Bicarb. Water		Bicarb. Water	Supp. Bicarb. Water		Bicarb. Water	Supp. Bicarb. Water
Sewage	145	147	—	—	—	—	—	—
2.5	630	850	142	488	708	40	19,500	28,300
5.0	815	1,530	139	676	1,390	20	13,500	27,800
7.5	1,040	2,230	135	905	2,095	13.3	12,000	27,900
10.0	1,165	2,980	131	1,034	2,850	10	10,340	28,500
15.0	1,600	4,240	124	1,476	4,115	6.67	9,800	27,400
20.0	1,900	5,500	117	1,783	5,380	5.0	8,950	26,800
30.0	2,600	8,340	102	2,500	8,240	3.33	8,350	27,500
40.0	3,330	9,150	88	3,242	9,060	2.5	8,100	22,600
60.0	4,690	14,300	58	4,630	14,240	1.67	7,750	23,800
80.0	6,090	17,500	29	6,060	17,470	1.25	7,550	21,900
W.S.L.	7,000	22,300	0	7,000	22,300	1.0	7,000	22,300

with the supplemented water fall fairly well along a straight line but there is definitely more curvature than in the previous cases. An explanation of this variation will be reserved as a part of the discussion. The results obtained with the different dilutions using the phosphate water were similar in character to those shown in Table I for bicarbonate water.

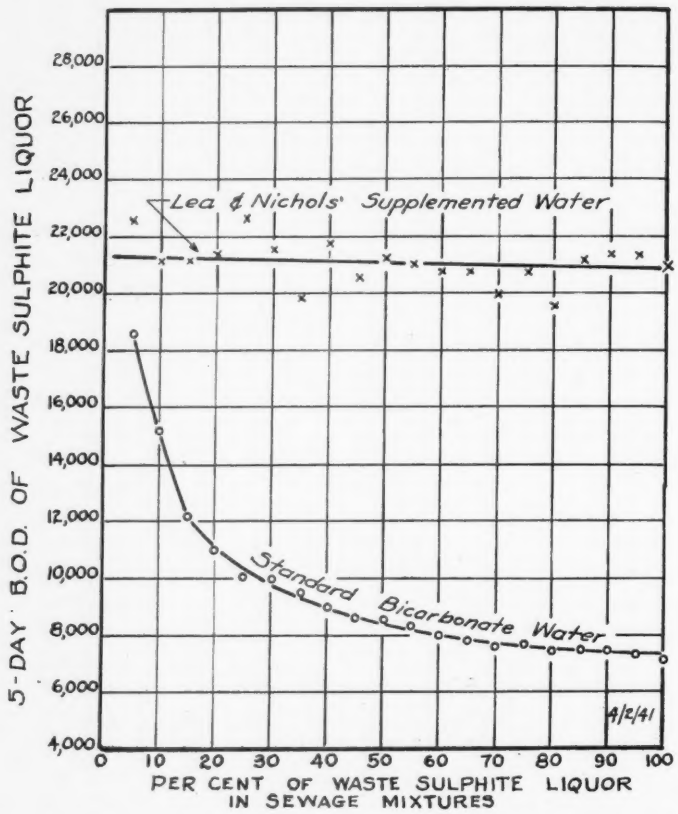

FIG. 1A.—Calculated 5-day B.O.D. values of a raw waste sulfite liquor based on the data shown in Fig. 1.

Because of the growing use of Formula C water of the U. S. Public Health Service (1) and the possibility that such a water supplemented with nitrogen may become our next standard water (16), a run was made to compare the results obtained with them and Lea and Nichols' modified supplemented bicarbonate water. The results are shown in Fig. 5. From this figure it will be noted that Formula C water gave results comparable to those previously obtained with bicarbonate and phosphate waters. When the Formula C water was supplemented with nitrogen the results were quite like those obtained with the supplemented bicarbonate water, but slightly lower when more than 30 per cent of waste sulfite

liquor was contained in the sewage mixtures. The erratic points obtained with Formula C water alone are rather unusual as compared to those obtained with the other waters. No sound reason for this variation is immediately apparent. Since the same mixtures of sewage and sulfite liquor were used for all the curves shown in Fig. 5, it does not appear that the sample and their dilutions were at fault.

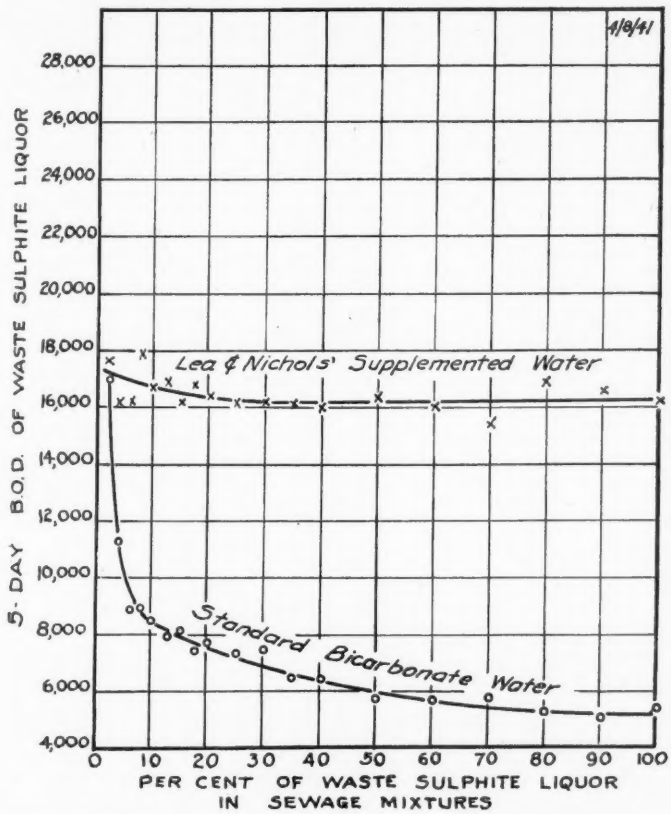

FIG. 2A.—Calculated 5-day B.O.D. values of a lime treated waste sulfite liquor (pH = 12) based on the data shown in Fig. 2.

In applying the test to determine whether the results obtained with the various dilution waters were comparable to those obtained in the presence of sewage, each B.O.D. value in Figs. 1 to 5 was corrected for the B.O.D. caused by the percentage of sewage it contained and the remainder was considered due to the waste sulfite liquor in the mixture. A B.O.D. for the sulfite liquor used was calculated from the percentage contained in the mixture. Representative calculations are shown in Table II. The results of these calculations are shown in Figs. 1*A* to 5*A*. From them it can readily be seen that, regardless of the dilution water used, the B.O.D. values obtained with the mixtures containing

low percentages of waste sulfite liquor tend to approach each other as the content of the waste decreased. This is, undoubtedly, a manifestation that a nearly ample supply of nutrient minerals was present in the B.O.D. bottle when the ratio of sewage was high enough, no matter which dilution water was used. In the case of the lime-treated waste, Fig. 2*A*, the calculated values obtained on the mixtures containing only 2 per cent of the waste checked very well for both dilution waters.

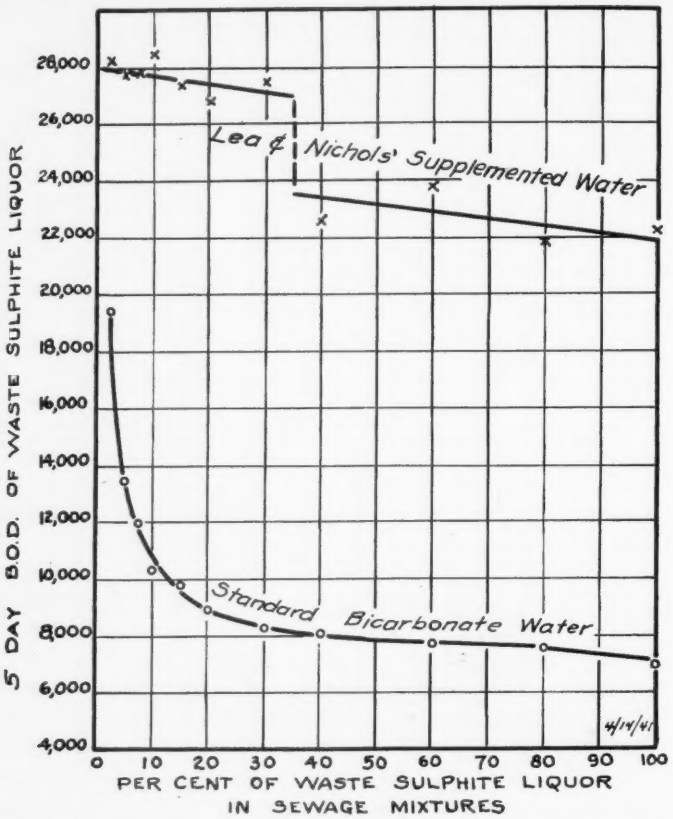

FIG. 3*A*.—Calculated 5-day B.O.D. values of a neutralized waste sulfite liquor based on the data shown in Fig. 3.

The first two runs, in which Lea and Nichols' supplemented bicarbonate water and standard bicarbonate water were compared, Fig. 1*A* and Fig. 2*A*, seemed to indicate that the former was nearly "ideal" in character, since the values obtained for the B.O.D. of the waste sulfite liquor were practically independent of the quantity of sewage used. However, the data obtained with neutralized waste, Figs. 3*A*, 4*A*, and 5*A*, have shown that calculated values obtained with the same water decrease more or less regularly as the percentage of sewage decreased in the mixtures used. It should, however, be noted that the calculated results

obtained with phosphate water and Formula C water are similar to the results obtained with bicarbonate water. The results with Formula C water were extremely erratic for some unexplainable reason. In the case of Formula C water supplemented with nitrogen, the calculated values were in close agreement with those obtained with Lea and Nichols' supplemented bicarbonate water when the percentage of sewage was high, but, as the percentage of sewage decreased, the values obtained

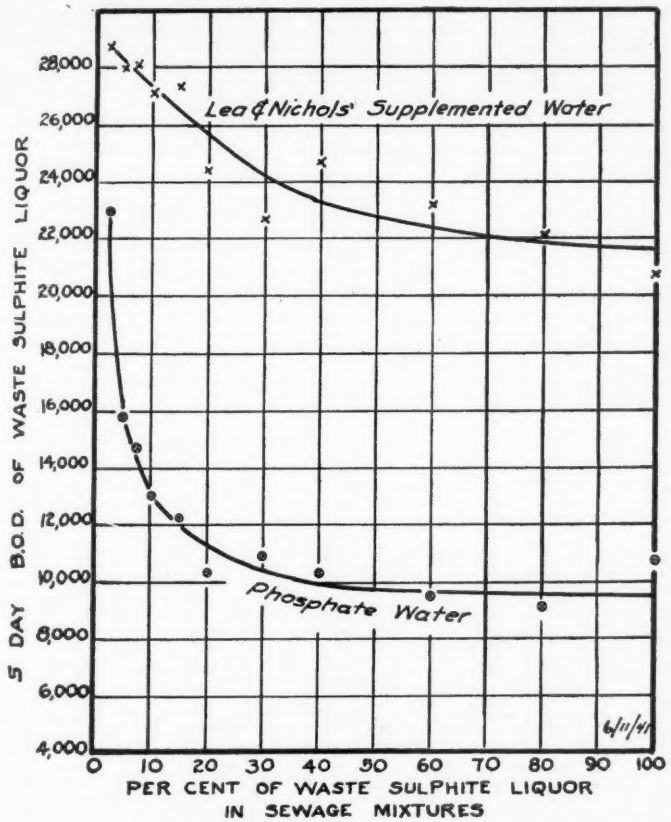

FIG. 4A.—Calculated 5-day B.O.D. values of a neutralized waste sulfite liquor based on the data shown in Fig. 4.

were less uniform and decreased at a more rapid rate. This indicates that the Formula C water supplemented with nitrogen is a less desirable water, in this case, than the supplemented bicarbonate water when the B.O.D. of waste sulfite liquor alone is to be determined. Unquestionably, Formula C, phosphate, and plain bicarbonate water should not be considered for measurement of the B.O.D. of waste sulfite liquor.

Had the experimental work reported in this paper been discontinued at the conclusion of the studies reported in Figs. 1, 2, 1*A*, and 2*A* we would have been led to believe that an "ideal" water for the determina-

tion of the B.O.D. of waste sulfite liquor had been developed. The results obtained with neutralized sulfite liquor and presented in Figs. 3, 4, 5, 3*A*, 4*A* and 5*A* indicated the water to be less "ideal," since the values obtained seemed to be influenced by the quantity of sewage present. Again the questions of seeding, mineral content and growth factors came to mind. In an effort to solve some of the questions, a series of samples were set up using a 3 per cent solution of glucose with a theoretical total

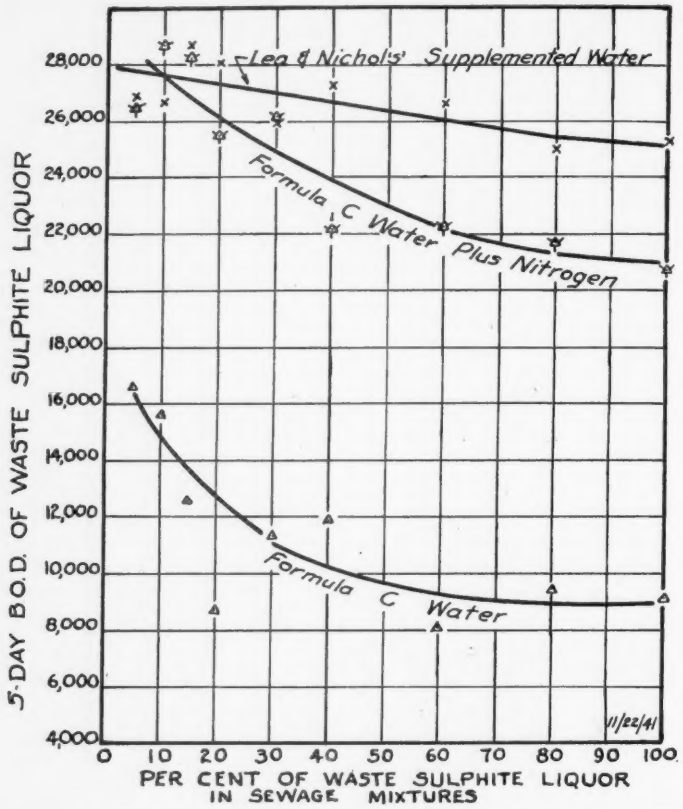

FIG. 5*A*.—Calculated 5-day B.O.D. values of a neutralized waste sulfite liquor based on the data shown in Fig. 5.

B.O.D. of 32,000 p.p.m. Mixtures of the glucose solution were made with sewage as in the previous studies and also with Bronx River water, to which had been added 25 per cent of sewage. At the same time a similar run was made with neutralized waste sulfite liquor, using sewage and Bronx River water for preparing the mixtures as with glucose. The series with river water were run to determine if a more varied flora and fauna, as might be supplied by a natural river water, would give different results than seeding with sewage alone. The glucose series were included with the specific purpose of determining the extent of

satisfaction of the theoretical or total B.O.D. which was accomplished in 5 days at 20° C. under the various conditions.

The results obtained with waste sulfite liquor, and also with the 3 per cent solution of glucose mixed with sewage or river water containing some sewage, are shown in Fig. 6*A*. From these data we learn that the addition of river water did not serve to increase the B.O.D. of either the sulfite liquor or glucose solution over that shown with sewage, and,

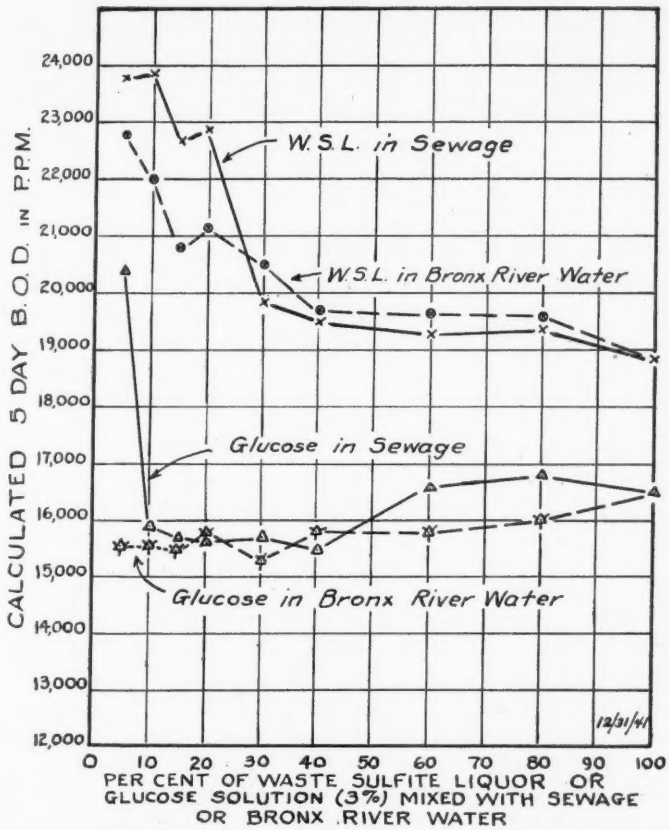

FIG. 6*A*.—Calculated 5-day B.O.D. values of a neutralized waste sulfite liquor and of a three per cent solution of glucose based on data not shown.

therefore, we can conclude that the life normally present in domestic sewage is well enough balanced to give maximum results with carbohydrate wastes. The fact that the calculated B.O.D. results for the glucose solution in the presence of sewage or river water did not exceed (except in one instance) those obtained for the pure glucose solution, when mixed with dilution water containing natural seeding from the air only, is proof that seeding can, in these cases, be very limited and still yield uniform and dependable B.O.D. results. Thus it appears that

seed is a minor but, of course, necessary part of the B.O.D. test. Determinations made at 20° C. of the bacterial numbers in the supplemented waters used in these experiments have shown them to contain from 3,000 to 8,000 organisms per milliliter.

In regard to mineral content and growth factors, the glucose studies indicated that the supplemented water alone provided enough of these to offset any value that might be derived from those contained in the sewage or river water. It should be noted that the trend of the data obtained with neutralized waste sulfite liquor corresponds to that previously found and that the higher values were obtained with sewage. A discussion of this will be presented shortly.

The determined 20° C. B.O.D. of the 3 per cent glucose solution was found to be in the neighborhood of 16,000 p.p.m. This value is only 50 per cent of the calculated theoretical oxygen demand of 32,000 p.p.m. and is somewhat lower than the values shown by Lea (14) of 56 to 63 per cent and those given in the Green Bay Pollution Survey, (11) which approximated 61 per cent. We have checked our value using glucose obtained from two other sources. That such a difference from the expected value of 70 per cent can occur indicates that the biological stabilization of industrial wastes may proceed at different rates than would be predicted from the relationship $y=L(1—10^{-Kt})$ which has been shown to apply for normal sewage pollution. Possibly carbohydrate matter is somewhat unusual, for Ruchhoft, Kachmar, and Placak (18) have shown the oxygen requirements of glucose, when stabilized by activated sludge, to vary from 11.3 to 31.8 per cent of the total demand, values which were much lower than those found for proteins.

Discussion

One of the interesting conclusions which practically all investigators of the B.O.D. test have reached is that natural waters, in general, yield higher results than those obtained with distilled or buffered distilled waters, in the B.O.D. of many industrial wastes. It has not, however, been recognized by many of these investigators that natural waters gave higher results mainly because of the fewer restrictions they imposed on the rate of biological oxidation. The results obtained with buffered distilled waters have been difficult to apply to prevailing natural conditions, to predict conditions which would be developed in a receiving body of water, because the variations in values obtained depended upon the purity of the distilled water and the size of samples or dilutions used in analysis. These limitations have prompted many to suggest that water from the receiving stream should in each case be used for the analyses. The difficulties which such a procedure would entail are many, especially where analyses are not done locally. Furthermore, the results and experiences encountered at one place are not directly applicable to any other similar situation.

Just what should be the characteristics of a desirable dilution water? It is our conclusion that any water which will give maximum uniform

B.O.D. values regardless of dilution factors is a desired or "ideal" water. Such water must contain all the necessary minerals which may be lacking in the case of certain industrial wastes and which are necessary to allow the unrestricted biological oxidation of carbohydrates, proteins, and fats singly or in any combination whatsoever. Suitable seeding material must also be provided. After all, it is understood that more than the theoretical quantity of oxygen can not be used in any event when limited seeding is used, unless end reactions such as nitrification occur. At the present time this does not appear probable in 5-day incubation at 20° C.

Since one of the desirable characteristics of the B.O.D. test is that it simulates natural conditions, and, therefore, allows us to evaluate the conditions which will develop in a stream or receiving body of water, the question will immediately be raised—why determine the B.O.D. under "ideal" conditions when the conditions in a river, lake, or harbor may be less than "ideal"? In answer one can say that it would be much wiser to make predictions of what might happen if the maximum or worst conditions can be evaluated than otherwise. It is the belief of the authors that further work will show the degree of limitation imposed by restricted mineral supplies (see Lea (14) Figs. 2, 4, and 5). If such is the case, the analysis of any natural water will allow B.O.D. information on industrial wastes, as determined in an "ideal" water, to be adjusted to the prevailing conditions in an intelligent and equitable manner by multiplying by a chemical or mineral factor whose value would normally be less than unity.

The results of the experiments just reported and the results shown by Lea (14) indicate that the modified formula of Lea and Nichols for supplemented bicarbonate water is the nearest approach to an "ideal" dilution water that has been proposed to date. In previous publications (15, 17) it has been shown by the senior author that the rate of B.O.D. removal from waste sulfite liquor-sewage mixtures by activated sludge was restricted when deficiences of nitrogen and phosphorus occurred. It was found through quantitative studies that approximately 3 p.p.m. of ammonia nitrogen and 1 p.p.m. of phosphorus were used in the stabilization of 45 p.p.m. of 5-day B.O.D. Application of these findings to the B.O.D. test indicated that a dilution water should contain at least 0.47 p.p.m. of nitrogen and 0.16 p.p.m. of phosphorus to prevent restriction of biological oxidation. The findings of Lea (13, 14), by an entirely separate technique, that 0.50 p.p.m. of ammonia nitrogen and 0.20 p.p.m. of phosphorus are necessary in dilution waters to be used on wastes deficient in these elements, indicate that rapid and slow biological stabilization of organic matter have nearly the same nutritional requirements, and should serve to develop confidence in our belief that information obtained in the laboratory through the medium of B.O.D. bottles and properly supplemented dilution waters can be translated directly to natural conditions.

Some comments are necessary concerning the decreasing B.O.D. values obtained for waste sulfite liquor, when neutralized waste was used

with supplemented bicarbonate water. Since the calculated B.O.D. decreased as the percentage of sewage in the mixture decreased, it could be concluded that the reduced quantity of seed, as furnished by the sewage, was responsible for the declining values. Such a conclusion, incidentally, would not be supported by the results obtained with acid or alkaline waste sufite liquor. It might be argued that acid or alkaline wastes had a detrimental effect on the more delicate organisms in the sewage and, thus gave results typical of those given by an unbalanced flora and fauna (dilution water with seed from air only).

However, before concluding that seeding is so important on such circumstantial evidence, it is well to inquire into another possibility which seems as likely to be the cause. It should be remembered that the organic portion of waste sulfite liquor consists of carbohydrate and ligneous matter. It is well known that the rate of biological stabilization of lignin proceeds much more slowly than that of carbohydrate matter and has been shown to be favorably influenced by the presence of carbohydrate matter (11). Undoubtedly, the samples with low sulfite liquor content and high sewage content had the greatest ratio of carbohydrate matter to lignin. Thus it would seem reasonable to believe that the stage of oxidation reached with respect to the lignin was more advanced in the mixtures containing the most sewage. This premise is substantiated by the fact that the lime-treated waste, from which practically all of the lignin had been removed, gave uniform results regardless of the percentage of sewage mixed with it. It would be denied, however, by the data obtained with the raw or acid waste sulfite liquor unless one suggests that the lignin was prevented from being oxidized because of the presence of sulfites. Let us turn our attention now to see what happened when neutralized waste sulfite liquor was mixed with sewage plus Bronx River water as far as seeding is concerned, and also study the results obtained with glucose in the absence of lignin. The data obtained with glucose, Fig. 6*A*, show definitely that the stage of oxidation reached was independent of the quantity of sewage or seed present, since the calculated B.O.D. values were fairly constant regardless of the dilution used for analysis, nor did the more diverse seeding supplied by the river water increase the B.O.D. of the waste sulfite liquor or glucose solution. Therefore, it would seem logical to conclude that the decreasing values obtained for the calculated B.O.D. of sulfite liquor were influenced by oxidation of the lignin. If such is the case, in wastes containing more than one type of oxidizable matter we may get B.O.D. values which are a function of the rates of stabilization of each of the components and the proportions of each present. The quantity of seed originally present could, conceivably, be a factor in determining the B.O.D. at any time if the growth phase of the organisms responsible for stabilization of one of the components is still in the ascendency or has not proceeded into the death phase far enough (see Lea (13)). With industrial wastes containing substances as resistant to bacterial decomposition as lignin, we may expect to find 5-day B.O.D. results as ob-

tained at different laboratories in slight disagreement despite the use of mineral supplemented waters. In any event, it can be conceded from the waste sulfite liquor studies herewith reported that the results will probably vary by not more than 25 per cent at the most. In view of the studies with glucose and sewage, it is concluded that the mineral supplemented bicarbonate water is as near "ideal" as can be desired for studies on carbohydrate wastes.

At the present time, it appears that we have at last been provided with ways of determining B.O.D. values of pure substances which can be relied upon for predicting what will happen under natural conditions. Studies on the rates of biological stabilization of pure compounds and mixtures of pure compounds which are representative of the three classes of food materials, carbohydrates, fats, and proteins, should give us much needed information concerning relative rates of stabilization and oxygen demands which will be of inestimable value in stream pollution control.

Precautions

In the use of mineral supplemented dilution waters there are several precautions which must be strictly observed. A few of them which have come to the attention of the authors are as follows:

1. Mineral salts should not be added until just prior to using the dilution water.
2. Fresh dilution water should be made each day that B.O.D. samples are set up.
3. Carboys or bottles containing remaining dilution water should be emptied and rinsed with distilled water immediately after use to prevent the development of algae. The rinsing of bottles prior to filling with distilled water is especially important for at least two reasons: (*a*) If the ageing of the distilled water is not done in a dark room, algae may develop and (*b*) Nitrifying organisms may multiply in any case, in light or dark, giving an initial seeding of organisms great enough to cause nitrification in the 5-day incubation test when wastes containing excess nitrogen such as domestic sewage are involved.
4. The use of supplemented waters containing ammonia nitrogen for the determination of B.O.D. should involve occasional parallel studies on nitrification, especially when incubation periods exceed 5 days.
5. Distilled water free from copper is essential for the determination of the B.O.D. of industrial wastes. This is of especial importance when limited bacterial numbers are present at the start of the incubation period. Present indications are that the copper content must be below 0.01 p.p.m. The danger of adding traces of this element in the mineral salts used for buffer and supplying the necessary mineral elements should not be overlooked. Copper determinations should be made on the prepared dilution water as well as on the distilled water.

Conclusions

1. The suitability of a dilution water for the determination of the B.O.D. of an industrial waste can be determined by analyzing a series of dilutions made with domestic sewage.

2. Lea and Nichols' supplemented bicarbonate water, as modified by Lea, and Formula C water supplemented with nitrogen, are suitable for the determination of the B.O.D. of carbohydrate wastes, the former being somewhat superior.

3. Seeding is a minor but necessary factor in the B.O.D. test. Natural seed in the dilution water *may* be sufficient, but a small inoculation with fresh sewage is a reasonable procedure.

4. The 5-day B.O.D. of waste sulfite liquor appears to be affected by the extent to which the lignin is oxidized. Indications are that results obtained at different laboratories using supplemented dilution water, such as that proposed by Lea, should check within 25 per cent.

5. The 5-day B.O.D. of a 3 per cent glucose solution was found to be independent of the amount of sewage or river water with which it was mixed and only 50 per cent of the total calculated oxygen demand.

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TREATMENT OF SEWAGE AND SEWAGE SLUDGE BY ELECTRODIALYSIS

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The use of electricity in the purification of sewage and waste products has been tried at various times during the last fifty years. Possibly the earliest application of electricity to the treatment of sewage was by Webster, 1888–1889 (1). This was an electrolytic process, using soluble iron anodes, and was investigated in several localities in England. In this process the screened sewage was passed through a flume 400 ft. long in which were placed iron electrodes parallel to the flow of the sewage. The potential drop between the electrodes, spaced 1 in. apart, was 1.8 volts with an anode current density of 0.9 amp. per sq. ft. The degree of purification of the sewage depended on its rate of flow through the flume, the strength of the sewage, and the current used. It was claimed that by this process a reduction of 60 to 80 per cent of the organic matter was obtained when using 450 kwh of electricity and 240 lb. of iron per million gallons, and with weaker sewages or longer detention a reduction of 87 per cent was claimed.

In this method of electrolytic treatment of sewage, the iron anode is dissolved and chlorine and oxygen are set free at the anode. Sodium hydroxide is formed with the evolution of hydrogen at the cathode. The intermingling of these products in the sewage electrolyte eventually forms ferrous carbonate and ferrous hydroxide, which effect some precipitation of the organic matter in the sewage. The chlorine or hypochlorites have also a pronounced bactericidal value; long treatment, it was claimed, would kill all the bacteria and the effluent would remain sterile.

About this time Webster devised a two-compartment cell in which the anolyte and catholyte were separated by porous tile. By continued electrolytic action on the sewage in the cathode compartment, using a carbon anode, the organic matter was reduced to ammonia and could be recovered. If sea water was electrolyzed in the anode compartment, chlorine accumulated and could be recovered. The primary object was not the treatment of sewage, but the preparation of ammonia from sewage and chlorine from sea water.

In 1893 (2) A. E. Wolff electrolyzed a strong brine solution, resulting in the production of chlorine and caustic soda, which were allowed to combine to form sodium hypochlorite. This was used for sterilizing sewage at Brewster, N. Y.

In 1896 (3) a modification of the Webster process was used for the coagulation of the muddy Ohio River water at Louisville, Kentucky. An elaborate series of tests was carried out to study the electrolytic method from an engineering, chemical, and biological standpoint. In

these tests, both iron and aluminum anodes were used, but lead, tin, zinc, and copper anodes were inadmissible for electrolytic decomposition on account of the formation of the salts of these metals and the objection to them in potable waters.

The results of these studies showed that this process assisted in coagulating the river water, but little reduction in the oxygen consumed values was obtained. In operation, the chief difficulty encountered was the acquired passivity of the anodes. Since the process was a means of forming hydrates of the metal of the anodes, any current not employed in dissolving the anodes was wasted. Aluminum anodes were early discarded, since one-half of the power was wasted in overcoming passivity and frequent removal and scraping was necessary. Reversal of the current was only a temporary expedient and frequently the normal power required would increase 100 per cent. The same difficulty, although to a less extent, was experienced with iron anodes. It was found that 10 per cent of the iron leaving the anode deposited on the cathode and it was estimated that the metal wasted as oxide scale amounted substantially to 50 per cent and under conditions of good practice the amount of power wasted would reach about 60 per cent. These conditions were not remedied by a potential difference from 1 to 220 volts, nor by current densities from 0.3 to 50 amps. per sq. ft. of anode surface.

In 1908 (4) the Webster process was placed in operation at Santa Monica, California. The sewage from a population of 34,000 was passed through a wooden flume, 30 ft. long, 22 in. wide and 18 in. deep, containing iron electrodes spaced 0.625 in. apart. A reduction of 40 per cent of the organic matter and merely a nominal removal of albuminoid ammonia and oxygen consumed was reported.

In 1911 (5) W. B. Bull electrolyzed a salt solution using a graphite anode and an asbestos diaphragm between the anode and cathode. From the cathode compartment he removed caustic soda and from the anode compartment a solution containing chlorine, hypochlorous and hydrochloric acid. This anolyte was then passed through a receptacle containing iron borings and the iron salts obtained were used as a coagulating chemical.

In 1912 (6) a plant similar to that at Santa Monica was installed at Oklahoma City, Oklahoma. The sewage treated amounted to 750,000 gallons per 24 hours. Little data are available regarding the removal of suspended solids or organic matter. However, it is reported that the bacteria removal amounted to 98 per cent.

In 1914 (7) the Landreth process of sewage purification was investigated at Elmhurst in New York City. This process differs from the original Webster process and its subsequent modified forms in that the iron electrodes are rendered practically insoluble by the large amount of lime added to the sewage.

The screened sewage was pumped through a wooden flume, 23 ft. long, 3 ft. wide and 3 ft. deep. In this flume were about 1000 iron electrodes, 16 by 10 in. and 1 in. thick, spaced ⅜ in. apart. Between these

electrodes 2000 paddles revolving at 19 r.p.m. effectively agitated the sewage. Before the sewage entered the flume, 1000 to 1300 p.p.m. of lime was added. The current density was varied from 0.6 to 2.6 amps. per sq. ft. and the power consumption was about 160 kwh per million gallons. By this method of treatment the oxygen consumed value was reduced about 62 per cent and the bacteria count 84 per cent. Later this process was investigated at Easton, Pennsylvania, and a plant may still be in operation at Winston-Salem, North Carolina.

The Webster process was again revived in 1932 (8) in Germany to reduce the pollution of the Niers, a tributary to the Maas River, and later experiments were conducted at the Rheydt sewage works. In these tests the electrodes were placed 0.39 in. apart with a potential drop of 1 volt. To overcome the disadvantage of this narrow electrode spacing, provision was made for blowing compressed air through the sewage to mix the tank contents thoroughly.

The oxygen consumption was reduced 45 to 50 per cent and the B.O.D. 60 per cent by the electrolytic decomposition of 49 p.p.m. iron and the use of 191 kwh per m.g. The detention time was about 15 minutes. With sewage highly contaminated by trade wastes the detention time was doubled, with a corresponding increase in iron and power consumption.

Later, it was reported that the electric current could be dispensed with and the ferric hydroxide could be obtained by reaction between iron filings and carbon dioxide with aeration. The amount of sludge precipitated in this iron-CO_2 process is large. It amounts to at least twice the fresh sludge quantity. This sludge can be digested, but during digestion the iron hydroxide passes into the sulfide, then to sulfate, and finally sulfuric acid, so that it must be well mixed with lime before using for agricultural purposes.

Other applications of the use of electricity in treating sewage and sludge are found in the patent literature, but there are no reports of actual tests or results.

From this brief survey it can be seen that since 1888 the electrical methods of treating sewage have depended on the solution of a metal anode, the formation of the hydroxide of this metal, and the flocculating value of the hydroxide on the sewage. The exceptions are the processes for the preparation of disinfecting and coagulating chemicals and the Landreth process, in which the anodes are insoluble at the high alkalinity to which the sewage is raised, but in this process it is probable that the large amount of lime added is responsible for the results obtained, and not the current applied.

Fundamentally the electrical purification of sewage is a process of chemical precipitation and the purification is practically the same as that obtained by the addition of metallic salts. In both cases, the fine non-settleable suspended matter is removed and much of the colloidal matter, but substances in true solution are unaffected.

Laboratory Experiments

In 1932 some tests were undertaken in the Department of Water and Sewage of Rutgers University, under the direction of Dr. Willem Rudolfs on the dialysis of sewage sludges.

The supernatant liquids from fresh, digested, and activated sludges were dialyzed through parchment paper against flowing water. Practically all the salts were removed in 72 hours and titration curves showed only a slight buffer effect and an isoelectric point of 3.4 pH. Hot dialysis was also used which hastened the removal of these salts about threefold. Examination of the ash of sludges showed that they contained some of the same ions that are widely used in the addition of chemicals to bring about the flocculation of sewage. Since these are removed by dialysis, a slow process, electrodialysis was tried.

Electrodialysis is electrolysis with the separation at the electrodes of the ions of the soluble salts or the products of their discharge.

The experiments were carried out in the following manner: 500 grams of sludge were placed in an unglazed vessel which was placed in a copper dish containing 500 grams of sewage. A carbon anode was placed in the sludge and the metal dish containing the sewage was the cathode. After passing a direct current the sludge became more readily filtrable and the sewage was flocculated as shown by the following figures:

Sludge	Per Cent Water Removed by Filtration
Untreated	12
Electrodialyzed 15 min.	43
Electrodialyzed 30 min.	65
Sewage	**Turbidity (p.p.m.)**
Untreated	450
Electrodialyzed 30 min.	Under 20

A cell was then constructed from a glass aquarium which was 3 ft. long, 6 in. high and 6 in. wide. This was divided into three compartments, separated by two ceramic tile membranes. Sewage sludge was placed in the center compartment and sewage in the adjoining compartments. A graphite plate 5½ by 5½ in. was used in the anode in the sludge and iron cathodes, of the same size, were placed in the sewage.

When a direct current was imposed, the pH of the anolyte or sludge was decreased and the pH of the catholyte or sewage was increased. After sufficient time, the sewage was completely flocculated and the sludge was so altered as to be satisfactorily filtrable without the use of any conditioning chemical. The ash content of the sludge decreased due to the migration of the cations to the sewage where they were discharged at the cathodes, forming hydrates of these metals, which coagulated the sewage. The anions, at the same time, migrating to the sludge, brought about acid hydrolysis and actual loss of solids as well of as ash.

It was of considerable interest to note that the oxygen consumed value of the system-anodic sludge and cathodic-sewage decreased during

the electrodialysis. These results indicated the possibility of a dual treatment of sewage and sewage sludge by electrodialysis.

Pilot Plant

In 1935 the Research Corporation of New York installed a pilot cell at the Plainfield-North Plainfield-Dunellen Sewage Treatment Plant through the courtesy of Mr. John R. Downes, Supervising Engineer, to determine the practical value of this dual sewage-sludge treatment.

The cell was a wooden tank, 12 ft. long, 3 ft. deep, and 3 ft. wide and was divided into three compartments longitudinally. The anode or sludge compartment, with a capacity of 110 gallons, was in the center, separated from the two cathode or sewage compartments by ceramic tile slabs, 2½ in. thick. The anode was composed of a series of graphite plates suspended from a bus bar in the center of the anode or sludge compartment. The cathodes were perforated iron sheets suspended from bus bars in each of the cathode or sewage compartments. Their distance from the tile membrane could be varied as desired.

Table I.—*Reduction in the Suspended Solids of the Sewage Treated in the Pilot Cell*

Raw Sewage Sus. Sol. P.P.M.	Effluent Sus. Sol. P.P.M.	Reduction Per Cent
232	37	83
246	50	79
248	62	75
250	35	86
261	51	81

	Per Cent
Avg. Reduction	80.8
Min. "	75.0
Max. "	83.0

Table II.—*Reduction in the B.O.D. of the Sewage Treated in the Pilot Cell*

Raw Sewage B.O.D. P.P.M.	Effluent B.O.D. P.P.M.	Reduction Per Cent
245	65	74
251	85	67
280	80	72
298	92	69
330	82	75

	Per Cent
Avg. Reduction	71.4
Min. "	67.0
Max. "	75.0

Sewage was pumped from the plant after screening and by the use of weirs its flow through the cathode compartments could be regulated at any desired rate. Aerators placed in the bottom of the cathode compartments kept the sewage in turbulence and prevented sediment from settling. The sewage left the cell by gravity and was settled in two conical steel tanks, each of 500 gallons capacity.

Previous laboratory tests had shown that it would be impractical to hold the sewage in the cathode compartments until it was completely

flocculated and clarified, so advantage was taken of the fact that less coagulant is required as the pH is raised. Equipment was placed at each cathode compartment to add a chemical coagulant when desired in any predetermined amount. This cell was in operation for six months and during the time the ceramic tile membrane was in use it showed no deterioration nor tendency to clog.

The detention of the sewage in the cathode compartments was about 30 min., which amounted to a flow of 14,000 to 15,000 gallons per day. An average of about 14 p.p.m. iron as ferric chloride and 0.2 cu. ft. of air per gallon was used.

After settling the sewage two to four hours, the resulting sludge was pumped to the anode compartment to replace that which had been conditioned. Some results obtained are shown in Tables I and II.

While the sewage was passing through the cathode compartments the pH of the sludge in the anode compartment was reduced to 3.4 and was readily filtrable without the use of conditioning reagents. During this reduction in pH the sludge was altered in other ways. The solids were reduced as much as 20 per cent and the ash content 30 to 40 per cent; the original putrescent odor was removed or much decreased and upon filtering more water was removed than by chemical conditioning and a drier filter cake of higher solid content obtained, as shown by the following figures:

Untreated Sludge pH	After Electrodialysis pH	Solids in Filter Cake Per Cent (Laboratory Filtration)
6.5	3.3	32
6.5	3.4	33
6.5	3.5	41
6.5	3.4	41
6.5	3.5	45

The sludge, after electrodialysis, had a lighter color, indicating a bleaching action. It settled rapidly; one liter of sludge in a cylinder settled to about 500 ml. in one hour. Apparently bacterial action was inhibited or partly destroyed since little or no gassing occurred upon long standing.

The loss in solids and ash of sludge subjected to electrolysis was considered of sufficient importance to justify additional controlled small scale laboratory investigations. These were carried out by Mr. L. N. Bonacci in the Department of Water and Sewage of the New Jersey Agricultural Experimental Station. The results of this study, which was based on the analysis of the sludge before and after treatment, are shown below:

Sludge Analysis

	Per Cent
Before Electrodialysis—Total Solids	3.4
Before Electrodialysis—Ash	30.15
After Electrodialysis —Total Solids	2.86
After Electrodialysis —Ash	19.45
Reduction in Total Solids	16 Per Cent
Reduction in Ash	76 Per Cent

The average reduction in total solids found during the operation of the pilot cell was 25 per cent and the reduction in ash 40 per cent.

Further examination of the electrodialyzed sludge showed a loss of 16.0 per cent of the total nitrogen and 3.5 per cent of the volatile matter and the presence of oxidizing agents equivalent to 930 p.p.m. Cl_2.

No satisfactory explanation can be given, at present, for many of the phenomena encountered in the electrodialysis of sludge and sewage. However, experiments using distilled water in place of either the sewage or the sludge and soluble anodes in place of insoluble ones offer some explanations which will be dealt with in subsequent papers.

While the tests on the pilot cell were carried out under as widely varying conditions as possible, the optimum current density seemed to be about 0.3 amp. per sq. ft. of anode surface.

Shortly after the pilot cell was placed in operation, it was evident that a large part of the electrical power was wasted in overcoming the resistance of the tile membrane. A more porous tile was tried and, while the resistance was lower, it was found to be structurally too weak. A large number of materials were investigated, including eight samples of filter cloth, asbestos, asbestos cement board, carborundum, carbon and woven glass. Finally asbestos cloth was chosen as meeting all requirements. The resistance of the asbestos was nearly one-tenth that of the 1½-in. ceramic tile. The asbestos cloth was attached to frames which were rigidly set in the cell. Later it was found that the asbestos could be sewed to the perforated iron cathodes, providing a much simpler and satisfactory assemly.

TABLE III.—*Fresh Sludge, 6.56 Per Cent Solids*

Conditioned, per Ton Dry Solids, by:	
Chemicals	Electrodialysis
89 lb. of $FeCl_3$	181 kilowatt hours
Moisture in filter cake 70 per cent	Moisture in filter cake 59.5 per cent
Solids in filter cake 2065 lb.	Solids in filter cake 1440 lb.
Water in filter cake 4665 lb.	Water in filter cake 2130 lb.
pH 6.2	pH 3.4

Table III shows the results of a typical test with this reduction in power, the power consumption (kilowatt hours) per ton of dry solids being applied to the sludge only.

While this sludge was being reduced to a pH of 3.4 in the anode compartment, sufficient sewage with an original pH of 7.1 and a turbidity of 411 p.p.m. had passed through the cathode compartment to provide sufficient sludge to again fill the anode compartment.

The following amounts of chemicals per million gallons were required to reduce the turbidity of this sewage to less than 20 p.p.m.:

	Chemicals Alone	Chemicals and Electrodialysis
$FeCl_3$ alone	725 lb. of $FeCl_3$	242 lb. of $FeCl_3$
Lime and $FeCl_3$	833 lb. of Lime 55 lb. of $FeCl_3$	416 lb. of Lime
Total sludge produced	5057 lb.	4172 lb. of sludge returned to the cell
$FeCl_3$ required for dewatering this sludge	226 lb. of $FeCl_3$	

The pH of 3.4 frequently mentioned above was found to be a critical value for the sludge. While the detention of the sludge in the anode compartment progressively increases its filtrability or decreases its chemical demand, it is at pH 3.4 that the best filtration rates and dryest filter cakes are obtained without any conditioning chemicals. Longer detention in the anode compartment and a consequent lowering of the pH below 3.4 brings about dispersion and loss of filtrability.

To prevent these undesirable features, it is necessary to remove the sludge as soon as a pH of 3.4 is reached. At the same time sufficient sludge must have been settled from the sewage which passed through the cathode compartments, to refill the anode compartment. Consequently, it is important to regulate the sewage flow through the compartments in proportion to its strength. The volume of a relatively weak sewage must be proportionately higher than a strong sewage to provide for the required amount of sludge.

The pH of the sewage passing through the cathode compartments increases from 7.3 to 8.3. This increase in pH reduces the chemical demand for coagulation. This increase in the pH of the sewage could also be obtained by the use of lime. In general, about 735 lb. of CaO per mg. would be required, which would cause an increase in the dry sludge of about 1000 lb. The changes brought about in the anodic sludge could not be duplicated by the addition of chemicals outside of the cell, as shown by the following:

Comparison of the Reduction in the $FeCl_3$ Demand of Sewage Raised to pH 8.1 by Lime and by Electrodialysis

	P.p.m. Fe as $FeCl_3$ to Reduce the Turbidity to Below 20 p.p.m.
Sewage pH 7.7	36.8 p.p.m.
Sewage limed to pH 8.1	30.5 p.p.m.
Sewage electrodialyzed to 8.1	24.5 p.p.m.

The changes observed in the sludge suggested the use of electrodialysis as a process of sludge conditioning alone. Sludge was placed in both the anode and cathode compartments. No filtrable sludge could be obtained from the cathode compartments. The sludge increased in pH, became diluted by cathosmosis, and developed a very putrescent odor.

Much has been claimed for the effects of the anodic oxygen and the sterilizing effects of the hypochlorites. That these do play a part is apparent in the changes brought about in the sludge. The effect of the cathodic hydrogen is not pronounced unless it assists in the conversion of the nitrogen to ammonia.

It was thought that a continuous process of sludge conditioning, instead of a batch process, might be used. This involved the periodic introduction of fresh sludge at one end of the compartment as the conditioned sludge is removed from the other end. The results were unsatisfactory with this cell construction. Some of the sludge apparently dropped below pH 3.4, losing its filtrability, which was not improved by mixing with sludge with a pH value above 3.4.

Summary and Conclusions

Laboratory experiments demonstrated that electrodialysis could be used to condition anodic sludge for filtration and to flocculate cathodic sewage at the same time.

A pilot cell was operated for six months to determine the commercial value of this dual treatment.

The resistance of a ceramic diaphragm increased the current consumption to an unattractive figure. When this was replaced by ordinary asbestos cloth, the power requirements were reasonable.

It was found to be impracticable to detain the sewage sufficiently long in the cathode compartments to obtain complete flocculation and clarification. Advantage was taken of the increase in pH by electrodialysis to decrease the amount of the chemical coagulant.

As the sludge decreased in pH values the filtrability progressively increased requiring less conditioning chemical until a pH of 3.4 was reached. At this pH value, the sludge was filtered readily without the use of conditioning chemicals.

The sludge must be removed from the cell when it reaches a pH of 3.4. If removed at a higher or lower pH the filtrability is less satisfactory.

Sufficient sludge must be obtained from the sewage passing through the cathode compartments, during the conditioning of the sludge, to replace this sludge when it is removed for filtration. To meet this condition the rate of flow of the sewage must be varied depending on its strength.

In addition to becoming filtrable, there is an actual loss of solids amounting to 20 per cent and a loss in ash of 30 to 40 per cent.

The most economical current density was about 0.3 amp. per sq. ft. of anode surface with a potential drop of about 4 volts between the electrodes. This amounts to about 200 kwh per ton of dry solids conditioned and also increased the pH of the sewage about one pH unit.

The cost of chemical and electrodialytic treatment will depend on the price of electricity and chemical coagulants. The results on a typical test indicated that 181 kwh are equivalent to 408 pounds of $FeCl_3$ and 416 pounds of CaO.

On dewatering chemically and electrodialytically treated sludge, the latter produces a cake of considerably lower moisture content than sludge treated with the optimum amounts of chemicals.

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Stream Pollution

AN ANALYSIS OF STREAM POLLUTION AND STREAM STANDARDS *

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Synopsis

This paper contains a compilation of data on the hourly, daily and other variations in stream conditions, analyzed from the viewpoint of indicating the many factors which must be considered in stream sampling and investigations. It also contains information on some of the standards of stream cleanliness now in use in this and foreign countries correlated with the object of the standard and stream use. The paper points out certain shortcomings in the methods of sampling in present use, and suggests for discussion certain alternative methods which are considered superior. The standards of stream cleanliness are critically analyzed. A bibliography on stream pollution is included. The primary purpose of the paper is to suggest increased consideration of certain phases of stream investigation and stream requirements, where further development is needed, so that when intensive activity in the sewage treatment field resumes in the post-war period, our knowledge and methods will be improved, to the end that the selection of the degree of treatment required in any particular case can be accomplished even more efficiently and economically.

Introduction

The following section contains data on the many variations in biochemical oxygen demand and oxygen content which occur hourly, daily, and over a stream cross-section. It will be shown that variations from oxygen depletion to supersaturated conditions can occur at any sampling point during the day; or at a given time and sampling station, the same variation occurs at different points in the cross-section. From the data included, the fallacy of taking grab samples indiscriminately, both with respect to time and sampling location, will be readily appreciated. The need for composite 24-hour knowledge of stream conditions will be clearly indicated. It is important that our sampling techniques advance to keep abreast of our increased technical knowledge concerning such factors as de-oxygenation and re-aeration and our improved methods of laboratory analysis.

* Presented at the Fifteenth Annual Convention of the Central States Sewage Works Association, Minneapolis, Minn., June 18, 1942.

Variations in Stream Conditions

Hourly Variation of Dissolved Oxygen in Various Rivers.—It is generally well recognized that the dissolved oxygen content of river waters varies during the hours of the day, depending upon a number of factors. Chart 1 shows the hourly variation for the Mississippi, Minnesota, Illinois and White Rivers. The data on the White and Illinois Rivers cover only a relatively short period of time, but on the Mississippi and

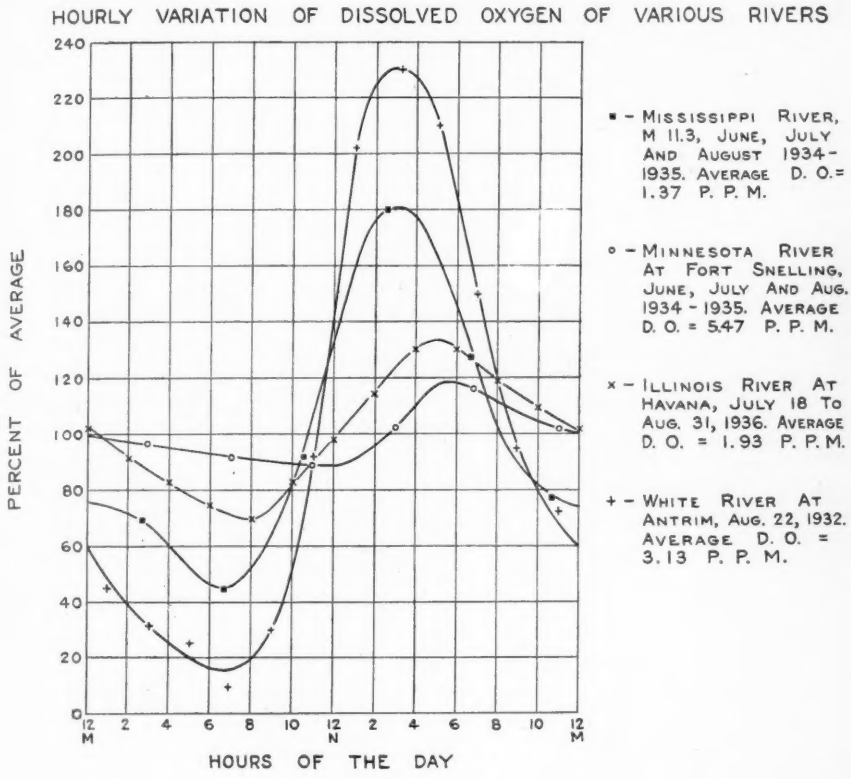

Chart 1.

Minnesota Rivers the data cover the months of June, July and August of 1934 and 1935, and include a large number of determinations. The Minnesota River shows the smallest variation, the peak concentration being 20 per cent more than the average concentration for the day. The Illinois River shows a maximum variation of 30 per cent. The Mississippi River has a peak which is 80 per cent above the average, and a minimum which is almost 60 per cent below. The White River shows a variation as high as 230 per cent above the average. It will be evident, from an inspection of this chart, that grab samples, particularly

at certain hours of the day, are likely to vary quite considerably from the average for the day.

Hourly Variation in Dissolved Oxygen for Various River Conditions.—The hourly variations in dissolved oxygen of a stream are affected by the average oxygen content of that water during the 24 hours. River waters with a low average concentration of dissolved oxygen vary considerably more than those with a higher concentration. Chart 2 shows the dissolved oxygen variation for the Minnesota and Mississippi

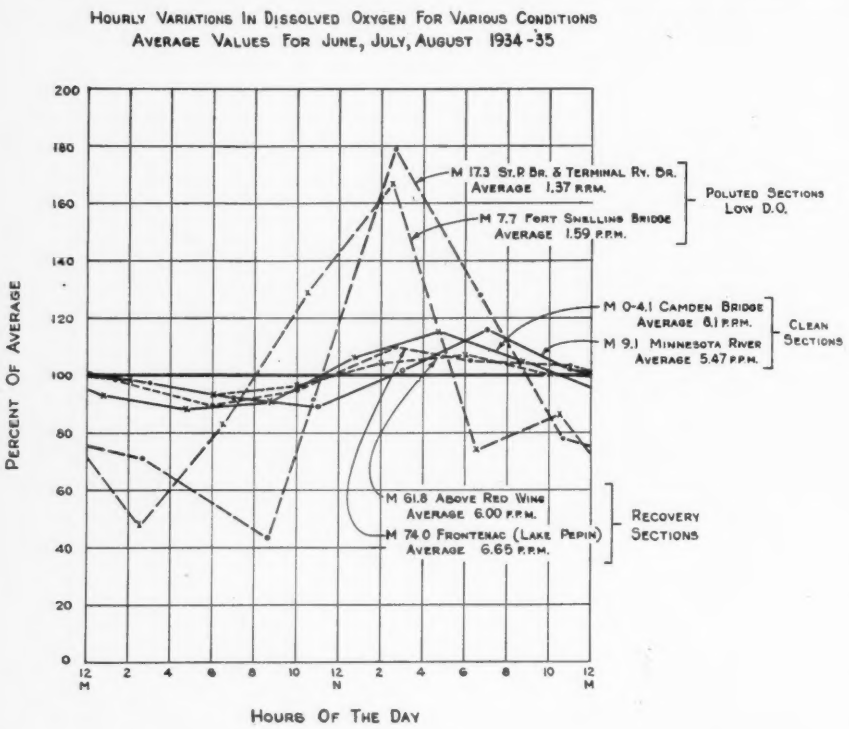

CHART 2.

Rivers at various points related to the stream condition, *i.e.*, clean sections, polluted sections or recovery sections. In the cleaner sections having a dissolved oxygen content from 5½ to 8 parts per million, the average maximum variation in dissolved oxygen is approximately 15 per cent above the average. However, in the polluted sections having average oxygen concentration in the neighborhood of 1½ p.p.m., the maximum concentration is 60 to 70 per cent above the average. In the recovery sections having an oxygen concentration of 60 to 6½ p.p.m., the maximum oxygen content is only 10 per cent above the average. It should be pointed out that the data shown in Chart 2 are based upon the average values for the months of June, July and August for 1934 and

1935, and that individual days will show very much greater variation than the averages indicated. The above data apply to summer months. Even during the winter months the oxygen concentration of streams varies widely, as shown by Chart 3, which includes similar data for the months of December, January and February, 1934 and 1935. The hourly variation here is not so great but for polluted sections containing an average of 1 p.p.m. of oxygen, the peak concentrations are 40 to

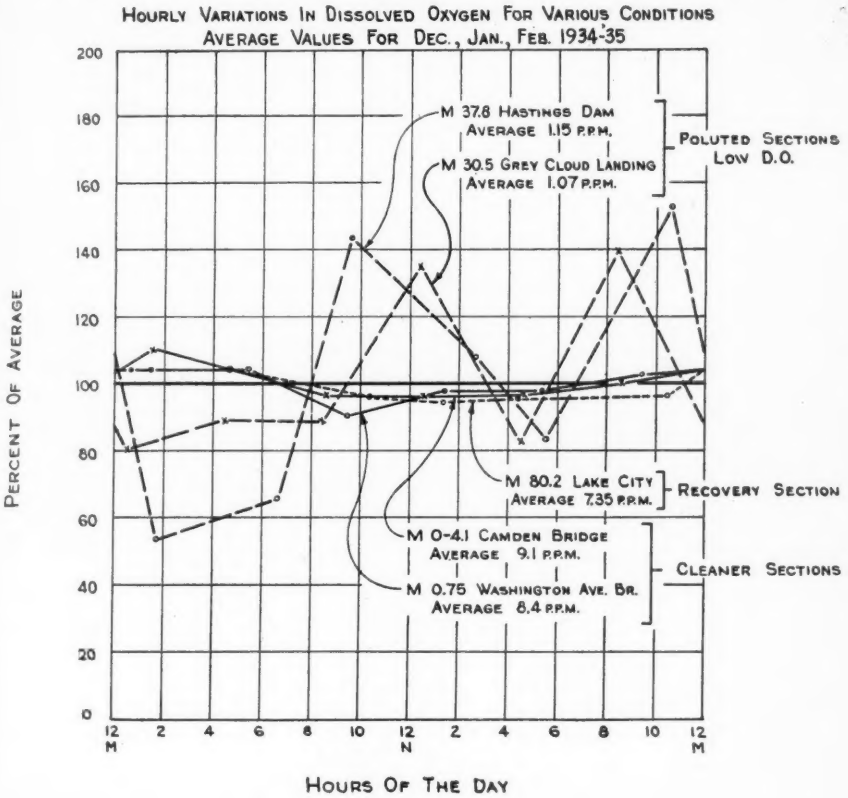

CHART 3.

50 per cent above the average. In the cleaner sections the hourly variations are only 5 to 10 per cent above the average. Table I shows the effect of the magnitude of dissolved oxygen concentration on the deviations from the average for the Mississippi, Minnesota and St. Croix rivers. It will be seen from this table that, in general, as the dissolved oxygen concentrations increase the hourly variations become less, to the point where, at saturation, the variations are relatively small. However, at concentrations below 2 to 3 p.p.m., the maximum average concentration is likely to be 150 per cent or more of the average, whereas, the minimum hourly concentration is likely to be as low as 30 to 50 per

cent of the average. It will be seen from these data that in the section of a river where oxygen concentrations are critical, from the standpoint of design or operation, namely, 2 or 4 p.p.m. or lower, that relatively large variations of dissolved oxygen occur during the different hours of the day. As an example, with an average concentration of 2 p.p.m. a minimum content during the day may be as low as 0.7 p.p.m., and the maximum as high as 3.6 p.p.m. All the values referred to herein are averages for the month of June, July and August, 1934 and 1935. Individual days during this period show very much larger variations than the averages listed.

TABLE I.—*Effect of Magnitude of the Dissolved Oxygen Concentration on the Deviations from the Average for June, July and August, 1934–35* [1]
Mississippi, Minnesota and St. Croix Rivers

Average Dissolved Oxygen P.P.M.	Average of Maximum Hourly Deviations from Average Per Cent of Average	Average of Minimum Hourly Deviations from Average Per Cent of Average
1.7	175	39
1.35	177	43
1.60	168	48
1.80 *	105 *	11 *
2.00	179	35
3.50	149	52
4.50	122	84
5.30	151	78
5.50 *	116 †	89 †
6.00	107	93
6.60	109	89
6.70	107	94
7.20 ‡	102 ‡	98 ‡
8.10	115	89
8.5+ (Saturation at Average Temperature of 24° C.)		

* Twin City Lock and Dam, Mississippi River.
† Minnesota River.
‡ St. Croix River.
[1] Average temperature 24° C. (Minimum monthly average 20° C., max. monthly temp. 28° C.).

Effect of Solar Radiation on Hourly Variation in Dissolved Oxygen.—One of the principal factors which affects the variation in dissolved oxygen encountered during different hours of the day is the intensity of solar radiation as it affects algae growth. It is generally recognized that days with very little sunlight will show much smaller hourly variations than will days with bright sun. As an example of this, Table II is included, which shows the effect of sunlight on the Mississippi River at a station near the down-river city limits of St. Paul. With an average concentration of 1.37 p.p.m. for the months of June, July and August, 1934–35, average peaks of 180 per cent of the average and minimum variations of 45 per cent of the average were found. However, on a day with a large percentage of possible sunshine, the peak concentration was 250 per cent of the average, and the minimum concentration

TABLE II.—*Effect of Solar Radiation on Hourly Variation of D.O. Mississippi River at Mile 11.3 (Downriver City Limits of St. Paul)*

Time	Dissolved Oxygen—Per Cent of Average		
	Avg. June, July and Aug. 1934–35	Sunlight Aug. 15–16, 1935	No Sunlight June 6, 1935
2:45 A.M.	70	3	117
6:45 A.M.	45	6	45
10:45 A.M.	93	70	70
2:45 P.M.	180	250	80
6:45 P.M.	129	190	125
10:45 P.M.	77	70	143
D.O.	1.37 p.p.m.	1.50 p.p.m.	1.75 p.p.m.

3 per cent of the average. In other words, for this day the minimum concentration was 0.05 p.p.m., and the maximum concentration was 3.75 p.p.m., a variation during the day from minimum to maximum of 75 times. On another day with no sunlight, the range was considerably reduced, with a peak of 143 per cent of the average, to a minimum of 45 per cent of the average.

Similar data on the Illinois River are shown in Table III. On a day of 99 per cent possible sunlight the peak concentration was 139 per cent

TABLE III.—*Effect of Solar Radiation on Hourly Variation of D.O.—Illinois River at Averyville, Ill. (Mohlman—Ind. Eng. Chem., 1931)*

Time	Dissolved Oxygen—Per Cent of Average	
	Aug. 24, 1927, 99% Possible Sunshine	Aug. 23, 1927, 40% Possible Sunshine
12 M.	87	100
2 A.M.	77	87
4	77	87
6	75	88
8	83	98
10	78	96
12 M.	92	98
2 P.M.	119	107
4	139	111
6	133	111
8	122	108
10	114	101
D.O.	8.65 p.p.m.	6.92 p.p.m.

of the average, whereas, on a day of 40 per cent possible sunshine, the peak concentration was 111 per cent of the average. The effect of sunshine on the average concentration on two subsequent days is also shown by this table. With presumably about the same river flow, the average oxygen content varied from 6.92 p.p.m. on a day with little sunshine to 8.65 p.p.m. the following day, with 99 per cent possible sunshine.

Similar data on the Minnesota River are shown in Table IV. As compared with a peak of 116 per cent of the average for the months of June, July and August of 1935, days with no sunlight showed a variation

TABLE IV.—*Effect of Solar Radiation on the Hourly Variation of D.O.—Minnesota River at Mendota (Junction with Mississippi River)*

Time	Dissolved Oxygen—Per Cent of Average				
	Average for June, July, Aug., 1935	No Sunlight		Sunlight	
		May 21, 1935	June 4–5, 1935	July 16–17, 1935	Aug. 13–14, 1935
3 A.M.	96	98	93	87	114
7 A.M.	92	101	88	79	83
11 A.M.	89	99	104	65	68
3 P.M.	102	100	107	117	70
7 P.M.	116	100	102	140	138
11 P.M.	102	98	95	112	128
Average D.O. P.P.M.	5.47	6.70	4.90	4.00	7.35

of only from 1 to 7 per cent above the average, whereas, days with a high intensity of solar radiation showed peaks of 38 to 40 per cent above the average.

Effect of Tidal Variation on Dissolved Oxygen Variation.—Tidal movements effect the quantity and character of the water passing any particular point. In Table V the dissolved oxygen content at the Narrows between upper and lower New York Harbor is shown compared to the tidal fluctuation. In this situation the average tide cycle is approximately 12.4 hours with a maximum concentration of 146 per cent of the average, and a minimum concentration of 56 per cent of the average. In this case approximately two cycles of dissolved oxygen

TABLE V.—*Effect of Tidal Variation on Dissolved Oxygen Content Dissolved Oxygen Variation Narrows—Between Upper and Lower New York Harbor*

Time: Hours Before Low Tide		D.O. in Per Cent of Saturation	D. O. in Per Cent of Average
7		45	101
6		55	123
5		62	139
4	Ebb	65	146
3	Tide	58	130
2	↑	51	115
1		45	102
—		—	—
0—Low Tide		37	83
Hours After Low Tide			
1		31	70
2	↓	25	56
3	Flood	28	63
4	Tide	35	79
5		42	94
5.4		45	102
		—	
Average		44.5	

Samples taken at Ft. Hamilton, 5 ft deep.
Average tide cycle 12.4 hours.

TABLE VI.—*Effect of Tidal Variation on Dissolved Oxygen Content Dissolved Oxygen Variation (Oakland Inner Harbor)*

Time	D.O. in Per Cent of Saturation	Tide Elevation in Feet	D.O. in Per Cent of Average
12 N.....	18	−3.0	87
2 P.M.....	20	−1.3	97
4	27	+0.2	130
6	30	0	145
8	27	−1.5	130
10	17	−3.0	82
12 Mid.....	8	−5.0	38
2 A.M.....	6	−4.3	29
4	15	−3.2	72
6	25	−1.0	120
8	28	+0.4	135
10	26	−2.3	125
12 N.....	22	−3.0	106
Average.....	20.7		

Dissolved oxygen. Estuary, Webster Street, October 8–9, 1940.
Average of 3 ft. and 20 ft. samples.

variation occur daily, with a 3 to 1 variation between the high and the low points of the dissolved oxygen curve.

In Table VI similar data are shown on the dissolved oxygen variation at the Oakland Inner Harbor. These analyses are based on an average of samples collected at 3-ft. and 20-ft. depths. Here again the maximum is 145 per cent of the average, with a minimum of 29 per cent of the average and 5 to 1 variation between the various hours of the day.

Effect of River Condition on Variation in Biochemical Oxygen Demand.—In Table VII the hourly variations in 5-day B.O.D. of the Mississippi River for the months of June, July and August, 1934–35, are

TABLE VII.—*Effect of River Condition on Variation in Biochemical Oxygen Demand (Mississippi River—June, July and August, 1934–1935)*

Sta.	Average D. O. P.P.M.	Average 5-day B.O.D. P.P.M.	Average of Max. Hourly Variation of B.O.D.		Degree of Pollution
			Above Avge.	Below Avge.	
−4.1	8.1	2.15	104.7	96.2	Zone of cleaner water
5.4	1.85	5.45	(114.8	81.2)	Zone of heavy pollu-
17.3	1.37	5.15	(116.9	77.6)	tion addition
22.6	1.20	6.85	(113.3	88.0)	Intermediate zone
30.5	3.47	7.12	(113.6	95.9)	
39.2	6.80	5.65	(107.4	90.6)	Zone of partial
61.8	6.00	3.95	(108.1	93.2)	recovery

TABLE VIII.—*Daily Variations in Dissolved Oxygen and Biochemical Oxygen Demand—Mississippi River Sta. 30.5—Grey Cloud Landing*

Date 1934	Dissolved Oxygen P.P.M.			5-day B.O.D. P.P.M.	Sun.	River Flow* C.F.S.
	Average	Max.	Min.			
Aug. 9–10	6.35	11.85	1.00	12.2	P.S.	860
Aug. 14–15	4.60	7.20	1.90	11.0	P.S.	810
Aug. 17–18	4.05	8.00	0.00	11.0	S.	980
Aug. 22–23	4.45	8.60	1.25	9.40	S.	870
Aug. 28–29	7.25	10.00	5.80	11.3	S.	700
Aug. 31	4.60	6.70	3.00	8.90	P.S.	821
Average, August	5.20			10.6		864
Sept. 6– 7	1.30	2.60	0.30	10.4	S.	965
Sept. 11–12	1.15	3.00	0.10	12.7	N.S.	1,075
Sept. 14–15	2.05	2.85	0.05	12.4	N.S. (Rain)	1,100
Sept. 25–26	0.45	2.65	0.00	10.8	N.S. (Rain)	1,875
Sept. 28–29	0.00	0.00	0.00	8.70	P.S.	1,515
Average, Sept.	0.85			11.00		1,143
Oct. 3– 4	0.05	0.15	0.00	7.70	N.S.	1,055
Oct. 9–10	0.20	0.50	0.00	8.50	P.S.	1,180
Oct. 12–13	0.65	2.60	0.00	—	S.	1,105
Oct. 17–18	0.55	1.55	0.00	8.50	N.S.	1,125
Oct. 26–27	0.75	2.25	0.00	5.60	P.S.	1,970
Oct. 31–Nov. 1	2.75	4.45	0.45	5.40	P.S.	1,780
Average, Oct.	0.80			7.15		1,523
Nov. 7– 8	3.15	4.20	2.30	5.75	P.S.	1,470
Nov. 13–14	1.65	2.15	0.90	5.80	S.	1,445
Nov. 16–17	3.50	12.55	0.15	7.50	P.S.	1,190
Nov. 22–23	5.25	6.55	4.00	8.15	N.S.	1,720
Nov. 27–28	1.05	1.25	0.70	5.55	N.S.	1,795
Average, Nov.	2.90			6.55		1,595

P.S.—Partial sun. S.—Sun. N.S.—No sun.

* U. S. Geo. Survey Record at St. Paul.

shown. It is indicated from this table that smaller variations in the neighborhood of 5 to 10 per cent above and below the average occur in the cleaner and recovery sections.

However, in the zones of heavy pollution addition and in intermediate zones, variations of 15 to 20 per cent above and below the average may be expected. In this table again the variations are based on an average over a long period of time. Daily variations are considerably greater. While the hourly variations in dissolved oxygen are commonly recognized to exist, the same variation in B.O.D. should be recognized and considered in all stream studies.

Combined Daily Variations in Dissolved Oxygen and Biochemical Oxygen Demand.—In Table VIII data are shown on the daily variations in dissolved oxygen and B.O.D. of the Mississippi River at Station 30.5 for various days during the summer and fall of 1934. The variations in oxygen content from day to day and from hour to hour is extremely large. Just as an illustration, the first two days on the table, August 9 and 10, and August 14 and 15, show a variation from 6.35 p.p.m. of dissolved oxygen on the first day, to 4.6 p.p.m. on the second day, in spite of the fact that river flow and solar radiation remain relatively constant. The extreme hourly variation in dissolved oxygen content on August 9 and 10 is interesting. The minimum oxygen content on this day was 1 p.p.m. and the maximum was 11.85 p.p.m. Looking at the last two days in this table the average oxygen content varied from 5.25 p.p.m. on November 22 and 23 to 1.05 p.p.m. on November 27 and

TABLE IX.—*Daily Variations in Dissolved Oxygen and Biochemical Oxygen Demand—Mississippi River Sta. 37.8—Above Hastings Dam*

Date 1935	Dissolved Oxygen P.P.M.			5-day B.O.D. P.P.M.	Sun.	River Flow* C.F.S.
	Average	Max.	Min.			
May 31–June 1	3.00	3.55	2.50	5.15	P.S.	4,675
June 5– 6	6.85	7.15	6.35	4.95	N.S. (Rain)	3,725
June 10–11	8.05	9.85	5.80	5.70	S.	3,735
June 18–19	2.40*	2.75	1.75	4.10	N.S. (Rain)	6,825
June 25–26	6.55*	7.40	5.90	3.40	S.	7,545
Average, June	5.35			4.65		5,573
July 8– 9	2.90*	4.40	1.90	3.70	P.S.	3,835
July 11–12	4.35*	5.50	2.95	3.90	P.S.	4,320
July 17–18	4.00*	4.80	3.40	4.35	S.	3,250
July 19–20	4.00*	5.95	2.80	3.85	S.	3,220
July 22–23	2.75*	6.00	1.40	4.00	S.	3,280
July 24–25	4.55*	8.55	1.85	4.10	P.S. (Algae)	3,140
Average, July	3.75			4.00		3,668
Aug. 5– 6	1.90*	2.20	1.55	5.80	N.S. (Rain)	3,340
Aug. 14–15	5.00*	5.85	4.10	5.75	S.	1,735
Aug. 19	3.25			4.45	P.S.	3,030
Aug. 20	4.30			4.75	P.S.	3,760
Aug. 21	3.80			5.25	S.	4,980
Aug. 22	3.25			5.05	S.	4,000
Aug. 26	3.85			4.40	P.S.	4,750
Aug. 27	6.65			5.60	S.	4,850
Aug. 28	6.95			5.10	P.S.	4,870
Aug. 29	6.85			5.10	P.S.	4,190
Average, August	4.60			5.15		3,331

P.S.—Partial sun. S.—Sun. N.S.—No sun.

* U. S. Geo. Survey Record at St. Paul.

28, in spite of the fact that river flows and solar radiation remained approximately the same. Similar variations obtain in the 5-day B.O.D. of the river water at this station, although not by any means as marked. For example, on the same latter two days considered the average B.O.D. varied from 8.15 p.p.m. to 5.55 p.p.m. In Table IX similar data for Station 37.8 and the summer of 1935 are shown.

Variation in Oxygen Across a River Cross-Section.—As an indication of the variation in dissolved oxygen at different depths and at various points in the river cross-section, the following data collected at Station 30.5, which is approximately 30 miles down stream from the center of pollution addition, are offered. These samples were collected on a sunny day between the hours of 1:40 P.M. and 2:10 P.M. The water depth in the main channel, where all the samples were taken, is 13 feet.

(*a*) Samples Collected 150 ft. from East Bank:

	D.O., P.P.M.	Per Cent Saturation
1 ft. Depth	12.55	138.0
3 ft. Depth	8.15	89.7
7 ft. Depth	1.65	18.2

(*b*) Samples Collected 50 ft. from East Bank:

4 ft. Depth	10.65	119.3
8 ft. Depth	0.65	7.2

Samples have been collected at a point in the Mississippi River a short distance upstream from a power dam which showed a variation from a supersaturated condition 2 ft. below the surface, to zero oxygen content on the stream bottom, 30 ft. below.

The extreme variation in these results shows the general unreliability of grab samples, particularly without a close study of variations across a river cross-section. Furthermore, a detailed study under certain flow conditions might be inapplicable under higher or lower flow-differing conditions.

General Discussion of Variations.—The wide variations in dissolved oxygen content of a stream from hour to hour, and from day to day, and over its cross-section, raise a serious question of the adequacy of the present sampling methods commonly employed in stream investigations. Because of the usual impracticability of continuous sampling throughout the day at any number of stations, methods should be developed by the sanitary engineer to secure more reliable results which will more nearly represent true and average stream conditions. When it is realized that millions of dollars are being spent for the construction and operation of sewage treatment works, it is extremely desirable that the basis of these designs be sound and correct insofar as stream knowledge is concerned.

Considering the present impracticability of securing, on a routine basis, composite twenty-four hour samples over a river stretch, various approaches to something nearing accuracy can be employed. The river

regimen should be carefully studied to permit the choice of sampling locations and depths which approach representative conditions. Some consideration should be given to the time of the day when samples are collected so as to approach the period when the oxygen is near its average value. A very careful mathematical analysis of the results of a year of 24-hour sampling on the Mississippi River indicated that the most favorable time to collect samples which would approach the average was generally between sundown and midnight. However, because of the unsuitableness of this time for usual sampling and laboratory work, a time during the morning between the hours of 7 A.M. and noon was selected. This is somewhat better than indiscriminate sampling, but yields results likely to be below the average concentration for the day.

While such approaches are somewhat more satisfactory than indiscriminate sampling, they are, in the main, lacking in desirable accuracy consistent with the funds being spent for sewage treatment. The profession should bend its efforts towards the development of accurate composite sampling methods. Several methods of securing automatic samples have been investigated by the Minneapolis-Saint Paul Sanitary District.

One of such possibilities investigated in cooperation with the manufacturers is the use of the dropping mercury electrode principle which has found use in industrial applications. By an adaption of the device, the dropping mercury unit would be installed at a representative sampling station in the stream and by means of an electrical circuit convey its impulses to a recording mechanism which would indicate directly and continuously the oxygen content. In addition to securing hourly variations and thereby average content, this device enables the eliminating of routine dissolved oxygen analyses except on a periodic check basis. Unfortunately, priority regulations preclude the installation of such equipment at the present time.

Another approach to the securing of composite samples has been conceived of by the author which he submits for consideration and discussion. Essentially, this consists of a pipe well of a certain capacity located on the stream bank connected by tubing to a sampling point in the stream where an intake would be located at a predetermined representative depth. Gravity would convey the river water into the pipe well (approximately 8 in. in diameter) from which an outflow, of such quantity as to maintain a 24-hour composite sample in the pipe well at all times, would be arranged. This overflow could be returned to the river by pumping, but to make the devise generally applicable, where power is not available, it is planned to discharge this overflow into barrels, of such capacity that they would suffice for the ordinary interval between sampling. At the time of sampling they would be pumped out, either by a hand or mechanical pump located on the sampling car or boat. With this arrangement composite samples for the previous 24-hour period could be collected from the pipe well at any convenient sampling time.

Possibly neither of these two schemes is the ultimate device which would be used after a period of trial or further consideration and development by the profession. It is the author's opinion that increased consideration should be given to such development, particularly by those responsible for the operation of treatment plants wherein the degree of treatment is adjusted to meet varying river dilution conditions. The fact that chemical treatment will entail an additional expenditure up to $1,000 per day at the Minneapolis-St. Paul plant makes this especially desirable at this plant.

Standards of Water Cleanliness

General.—There has been an increasing tendency in the past ten years to raise the standards of water cleanliness. Where this has been associated with a detailed study of the fundamental uses to which the waters are put and the overall economy of the expenditures necessitated thereby, as against benefits received therefrom, this increase in requirements is to be commended. Much too often, however, standards neglect the fundamental economic consideration of the ability of the streams to receive and assimilate pollution, as in the case of certain state requirements as to a standard end product in the effluent throughout the state, without regard to whether the effluent discharges into a dry run or into an immense body of water, and the correlated factor of whether the sewage results from a town of several hundred or a large city of several hundred thousand. The adoption of such standards neglects entirely the consideration of the diluting capacity of a stream and the uses to which it is put. What may be reasonable standards in an area of recreational use would be prohibitive and wasteful in one in which the principal stream use was industrial. Furthermore, such standards represent a retrogression in fundamental principles. The pendulum has swung to both extremes of thought already. Streeter (*S. W. J.*, **10**, 747) has stated that before 1850 complete reliance was placed on natural purification of streams and, that afterwards, for a period of about 50 years, no consideration was given to self-purification. He felt that now we have settled on a happy medium in this regard. Apparently we haven't. Wolman (*S. W. J.*) in October, 1940, deplored the present tendency to arbitrarily raise standards and suggested a somewhat greater consideration of the C.O.D. (Cost on Delivery) value as compared with the B.O.D. value.

What engineers should be concerned over even more than the arbitrary raising of standards is the present tendency to "standardize on standards." One state copies the standards of another almost verbatim, without regard to differing conditions. It is bad enough to adopt standards in one state which do not take into account the varying conditions existent therein, but to apply those standards to a distant state, neglecting entirely the many factors which affect stream pollution and use, and which, therefore, on the face of it should make every situa-

tion a separate subject for investigation, is fundamentally unsound. Concerning this, Sedgwick describes standards of sanitation as "devices to save lazy minds the trouble of thinking." He states further "Standards are often the guess of one worker, easily seized upon, quoted and requoted, until they assume the semblance of authority." This is a very deep criticism of the sanitary engineering profession and should awaken a desire to at least be original in our "standards" if standards there must be. A need for a "Stop, Look and Listen" period of clear thinking is clearly indicated.

With reference to this question, Wolman (*S. W. J.*, **12**, 1116) has this to say: "The trend, furthermore, is toward the adoption of standards on a wide geographical base by repeating the standards promulgated elsewhere, not always with the local conditions of use and necessity dominant. This is not at all an unusual procedure in the making of standards. The fallacies as well as the validities of an existing standard tend to be perpetuated in succeeding ones. . . . In most standards, however, the philosophy predominates, that in the absence of knowledge, the more rigid the standard, the safer the engineer,"

Perhaps the clearest and most authoritative statement concerning the undesirability of uniform standards was contained in the Third Report of the Special Advisory Committee on Water Pollution of the National Resources Committee. In this report the following statement is contained:

> For these reasons—the differences in natural water quality, the variations in stream flow, and the differences in human requirements—abatement of water pollution in the United States could not be advanced appreciably by setting up rigid or uniform standards of water quality. On the contrary, it would be greatly retarded by such a procedure. No single standard is applicable generally, but it is practicable and desirable to set standards for selected portions of drainage basins with due regard for the natural condition of the water and for its present and potential use. The key problem in planning for pollution abatement is to find the standards in each section of a stream which express the best balance between the stream's use for receiving and assimilating sewage and other waste and its use for other purposes, aesthetic and economic.

In a report on "Standards of Water Purity" by a committee of the A. P. H. A., presented in October, 1940, the following summary statement is made:

> While it is granted that standards of purity or sanitary classifications of streams and sewage effluents are helpful to persons and agencies charged with the responsibilities of reducing and preventing the pollution of waterways, standards should not be used as an excuse for the lack of application of known principles of sanitary science.

Samuel A. Greeley, in *Transactions* of the Illinois State Academy of Science, December, 1930, stated in a general way the more common uses of receiving waters from the standpoint of standards, as follows:

> Desirable standards of stream cleanliness depend in large measure upon the use which is made of the stream and the balance between the damage from pollution and the cost of corrective measures. The more obvious yard-sticks for stream cleanliness may be noted as follows:

(*a*) The natural state.
(*b*) The drinking water standard.
(*c*) The preservation of fish.
(*d*) Safety for agricultural use as stock watering and irrigation.
(*e*) The use of water by industry.
(*f*) The recreational standard.
(*g*) Freedom from nuisance.
(*h*) The use of water by commerce (navigation).

Abstract of Standards in Effect, or Recommended for Use by Various Authorities

In the following section the standards of a number of public bodies are presented in summary form. Because the author has, for convenience, taken the license of summarizing the various standards, it is suggested that the reader refer to the original sources if any important use is to be made of these data.

It will be noted that some of the standards define the quality of the receiving body of water, some define the characteristics of the sewage discharge or effluent, and, as Wolman has stated, "others range happily on both sides."

(1) *Standards Suggested by Imhoff and Fair.*—Imhoff and Fair (*Sewage Treatment*, 1940) classify receiving waters as follows:

Class	Use	Standards
D	Rough industrial uses and irrigation	Absence of nuisance, odors and unsightly suspended floating matters; dissolved oxygen present.
D	Fishing	Dissolved oxygen content not less than 3 and preferably 5 p.p.m. CO_2 not more than 40 and preferably 20 p.p.m.
B	Bathing, recreation and shellfish culture	No visible sewage matters. Bacterial standard; less than 100 *B. Coli* per 100 c.c.
A	Drinking water after chlorination	Without filtration, bacterial standard; less than 50 *B. Coli* per 100 c.c.

(2) *Standards of the British Royal Commission for Sewage and Sewage Disposal, 1912.*—The following standards were developed to satisfy the requirements of small streams draining densely-populated areas (for the relatively strong sewage of British communities).

Classification of Standard	Required Condition of Sewage on Effluent, P.P.M.		Type of Sewage Treatment Presumably Satisfying the Standards
	5-day 65° F. B.O.D.	Suspended Solids	
A. General Standards	20 or less	30 or less	Complete treatment
B. Special Standards			
Dilution *			
150 to 300	—	60 or less	Chemical treatment
300 to 500	—	150 or less	Plain sedimentation
Over 500	—	—	No treatment required

* Ratio of receiving water to sewage flow.

The basis of the above standards is that the 5-day 65° F. B.O.D. of the receiving water immediately below the point of sewage discharge should not exceed 4 p.p.m., in order to maintain satisfactory conditions at low flows at 65° F. river temperature.

(3) *Standards of Tri-State (Connecticut, New York and New Jersey) Sanitation Commission, 1936.*—(Applies to Tidal Waters in New York City Area.)

Class	Standards
Class A. Waters expected to be used primarily for recreational purposes, shellfish culture, and development of fish life	
(1) Floating Solids	Full removal.
(2) Suspended Solids	At least 60 per cent removal.
(3) *B. Coli*	Probable number shall not exceed 100 per 100 c.c. in not more than 50 per cent of samples of sewage effluent.
(4) Dissolved oxygen	Average dissolved oxygen saturation, not less than 50 per cent during any week of the year.

Class	Standards
Class B. All other waters.	
(1) Floating Solids	Full removal.
(2) Suspended Solids	At least 10 per cent removal plus additional if needed to prevent sludge deposits.
(3) *B. Coli*	No requirement.
(4) Dissolved Oxygen	Average dissolved oxygen saturation, not less than 30 per cent during any week of the year.

(4) *Ohio River Valley Water Sanitation Compact, 1940.*—This compact includes a general statement at the outset, that it is recognized that no single standard is applicable in all parts of the District due to such variable factors as size, flow, location, character, self-purification and usage of waters within the District, and goes on to say: "The guiding principle of this compact shall be that pollution shall not injuriously affect the various uses of interstate waters." General requirement is treatment so as to provide for substantially complete removal of settleable solids, and the removal of not less than 45 per cent of the suspended solids, provided that in order to protect the public health or to preserve the water for other legitimate uses, in specific instances such higher degree of treatment shall be used as may be determined to be necessary by the commission.

(5) *Interstate Commission (New Jersey, New York and Pennsylvania) on the Delaware River Basin.*

	Zone 1	Zone 2	Zone 3	Zone 4
(1) Effluent free of noticeable floating solids, color, oil, grease, and ..... free of suspended solids and sleek.....	Practically		Substantially	
(2) Free of turbidity to point that no ..... turbidity of Delaware River.....	Noticeable		Substantial	
(3) Required B.O.D. removals, %.....	85	85	35	—
(4) B.O.D. of effluent (Max.) P.P.M.....	50	100	—	—
(5) Allowable reduction of D.O. in river, %.	5	10	—	—
(6) Reduction of suspended solids.....	—	—	55	55
(7) % saturation of D.O.....	—	—	50	No nuisance
(8) Bacterial standard				
(*a*) Most probable no. of *Coli-Aerogenes* shall not exceed 100 per 100 c.c. in more than ....% of the samples of effluent.....	10%	25%	—	—
(*b*) No single sample shall contain more than .... organisms in 100 c.c.	10,000	10,000	—	—
(9) Sufficiently free of acids, alkalies, and other toxic and deleterious substances so as not to cause menace through use of waters for water supply, recreation, bathing, agriculture, industry, etc., nor be inimical to fish, animal, and aquatic life (see zones).....				
(10) Effluent must be free of offensive odors..	Yes	Yes	—	—
(11) Effluent shall be .... free of substances capable of producing offensive tastes or odors in public water supplies.....	Free	Free	Practically	Practically

Zone 1 extends from headwaters to a point just above Trenton, N. J.
Zone 2 extends from Trenton, N. J., to Delaware State Line.
Zone 4 extends from Delaware State Line to tidewaters of Chesapeake Bay.

(6) *Mississippi River Below St. Paul.*—For the Mississippi River below Minneapolis and St. Paul, the Minnesota State Board of Health, cooperating with the Wisconsin State Board of Health, in 1928 set up the following requirements:

> The pollution of the Mississippi River should be restricted to such an extent that the public health hazard will be reduced to a minimum, that the health of livestock will not materially be endangered, that the present public nuisance will be eliminated, and that fish life in the river, at least below the mouth of the St. Croix, will not be jeopardized.

Because these requirements were expressed in very general terms, several conferences were held with the State Board of Health as a result of which the following interpretation was arrived at:

(*a*) For the prevention of nuisances in the Hastings Pool: (1) Two p.p.m. of dissolved oxygen shall be maintained 90 per cent of the time for each of the various summer months. (2) One p.p.m. of dissolved oxygen shall be maintained 100 per cent of the time during each of the various summer months. (3) At least a trace of dissolved oxygen shall

be maintained during periods of absolute minimum flows prevailing for periods of 3 to 5 days.

(*b*) For the preservation of fish life: (1) The degree of treatment shall be increased above that required to meet the above standards if they do not permit the maintenance of about 4 p.p.m. dissolved oxygen below the St. Croix.

(7) *Illinois and Des Plaines River.*—L. R. Howson and C. B. Burdick, in a report to the District Engineer at Chicago, recommended the following standards for the Illinois and Des Plaines Rivers:

In the consideration of sewage treatment works that will be required under various drafts of dilution water from Lake Michigan, it has been necessary to fix a standard of maximum pollution for the Chicago Drainage Canal in order that reasonable sanitary conditions may be maintained in the Des Plaines and Illinois rivers. We suggest the following as a reasonable standard:

The liquid discharged by the Drainage Canal, as evidenced by the average of representative samples taken from any 30 consecutive days shall: (*a*) Be practically free from settleable solids deposited in 2 hours, and, (*b*) Shall contain dissolved oxygen equal to or exceeding the biochemical oxygen demand of said liquid for 5 days when incubated at 20° C.; (*c*) Shall contain not less than 3 parts per million of dissolved oxygen.

(8) *Metropolitan Sewerage Commission of New York.*—The Metropolitan Sewerage Commission of New York (*Proc.*, A. S. C. E., March, 1926) proposed standards as follows:

(1) "Garbage, offal, or solid matter recognizable as of sewage origin shall not be visible in any of the harbor waters.

(2) "Marked discoloration or turbidity, effervescence, oily sleek, odor or deposits, due to sewage or trade wastes, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.

(3) "The discharge of sewage shall not materially contribute to the formation of deposits injurious to health or navigation.

(4) "The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to the drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows, or in the Arthur Kill."

(9) *Michigan Stream Control Commission Classification.*—In 1933 the Michigan Stream Control Commission published the following classification of various waters:

B. Coli Index per 100 c.c.	Type of Water
0	Water free from pollution.
0–1	U. S. P. H. S. drinking water standard.
10–100	Good water, normal for inland and Great Lakes, free of sewage pollution.
100–500	Normal for inland streams, free of detrimental sewage pollution; attributed to land wash.
1,000	Suspicious—indicates mild pollution in natural waters, but dangerous in proximity to fresh sewage pollution.
10,000	Definite evidence of fresh sewage pollution—menace to health.
100,000	Heavy sewage pollution—definitely bad.
1,000,000 or more	Normal sewage.

(10) *Pennsylvania Sanitary Water Board Classification.*—The Pennsylvania Sanitary Water Board classified the waters of that state as follows:

Class A: Relatively clean and pure streams, unpolluted or uncontaminated from any artificial source, suitable for domestic water supply after chlorination. Artificial pollution of such streams is prohibited and a high degree of treatment of any sewage or industrial waste is required before its discharge into them.

Class B: Streams in which pollution shall be controlled, the degree of control to be dependent upon the general public interests and economics in each particular case.

Class C: Streams so polluted that their control or recovery is not economically feasible or advisable beyond the prevention of nuisance or menace to health.

(11) *Water Standards of State of Indiana, Adopted November 21, 1935.*—Determination of Qualities and Properties of Waters Which Indicate a Polluted Condition:

(1) If it contains an appreciable amount of grease, scum or floating sludge.

(2) If there are sludge deposits on the beds or banks, except in the immediate vicinity of sewer outlets.

(3) If the average dissolved oxygen during any 24-hour period, based on hourly samples, is less than 50 per cent saturation, or less than 25 per cent saturation at any time.

(4) If the water is toxic to animal or fish life.

(5) For bathing, if *Coli-Aerogenes* count exceeds 100 per 100 c.c. in more than 50 per cent of the samples, or shall exceed 1000 per 100 c.c. in any single sample.

(6) As a source of water supply, if the maximum *Coli-Aerogenes* shall exceed 5000 per 100 c.c. at any time at the intake.

(12) *General Regulations of the Oregon State Sanitary Authority.*—Class A: "Bodies of water in relatively clean condition used, or which may be used, for public water supplies, swimming and recreation, for irrigation, for the propagation of game and commercial fish, and for the propagation of shellfish; or bodies of water which, because of insufficient flow, cannot receive without detriment, wastes other than those having been given a high degree of treatment.

"Municipal or sanitary sewage shall be so treated prior to discharge into a Class 'A' water that the effluent from the treatment plant:

"(1) Shall be free of noticeable floating solids, oil, grease, sleek, and practically free of suspended solids.

"(2) Shall indicate an average 5-day biochemical oxygen demand reduction of not less than 85 per cent and at no time shall the residual effluent B.O.D. be in excess of 50 p.p.m.

"(3) Shall not reduce the dissolved oxygen in the receiving body of water more than 10 per cent.

"(4) Shall not, at any time between May 15 and October 1 of each year, contain more than 500 coliform organisms per 100 ml."

Class B: "Bodies of water which are used or which may be used for public water supplies, swimming and recreation, for the propagation of game and commercial fish, or for the propagation of shellfish, and which, in the opinion of the state sanitary authority, provide sufficient dilution to obviate the necessity for the degree of treatment required under Class 'A' waters.

"Municipal or sanitary sewage shall be so treated prior to discharge into a Class 'B' water that:

"(1) The effluent from the treatment plant shall be:

"(*a*) Free of noticeable floating solids, oil, grease and sleek.

"(2) The treatment plant shall effect:

"(*a*) A reduction in suspended solids of at least 55 per cent.

"(*b*) A reduction in the (5-day) biochemical oxygen demand of not less than 35 per cent and at no time shall the residual effluent B.O.D. be in excess of 125 p.p.m."

Class C: "Class C waters shall be those bodies of water into which the temporary discharge of untreated sewage may be permitted if, in the opinion of the State Sanitary Authority, such discharge may not be detrimental to any reasonable use of said waters. Temporary permits for the discharge of untreated sewage shall be obtained from the State Sanitary Authority, provided, however, that no such permit shall be valid for a period of time longer than three years, and, further, that such permits may be revoked for a cause at any time after the date of issuance thereof."

Requirements of Various Other States

Minnesota.—Formerly each problem of pollution was investigated separately and recommended accordingly. At present a uniform degree of treatment is specified for all cases, providing for an effluent containing not more than 25 p.p.m. of suspended solids and not more than 20 p.p.m. of 5-day B.O.D. Where there is a direct health hazard involved in the use of the stream, chlorination of the effluent should be provided.

Wisconsin.—In 1927 adopted a minimum D.O. of 2 p.p.m. Now endeavors to maintain 4 p.p.m. under low flow and high temperature conditions.

Ohio, Illinois and Maryland.—No standards. Each problem of sewage or waste treatment considered separately.

Standards in Relation to Use

In the following discussion the standards of cleanliness of waters is presented under the six headings, related to the water use:

(1) Source of Water Supply
  (*a*) Domestic
  (*b*) Industrial
(2) Recreational Use
  (*a*) Bathing
  (*b*) Boating
(3) Fish and Aquatic Life
(4) Agricultural
  (*a*) Livestock Watering
  (*b*) Irrigation
(5) Navigation
(6) Prevention of Nuisances

(1) (*a*) Standards of Waters Which Serve as Source of Domestic Water Supply Standards Suggested by U. S. Public Health Service

1. Drinking Water.—B. Coli index shall not exceed 1 per 100 c.c. and no more than 5 per cent of the samples shall have an index of 6 or more per 100 c.c. This has been generally accepted standard to date. However, recently the states signatory to the Upper Mississippi and Great Lakes Drainage Basin Sanitation Agreements have begun a co-operative study leading to the possible establishment of higher standards of purity for drinking water. The proposed standards would reduce downward the *B. Coli* index to 0.2 (Phelps) or .22 M.P.N. per 100 c.c. of the treated water. As stated in the preamble, the apparent reason for raising the standards is the reduction of epidemics of gastro-enteritis, believed to be traceable to drinking water.

2. Raw Impounded Underground Waters to be treated by chlorination only. *B. Coli* index shall not exceed 50 per 100 c.c.

3. Raw Surface Waters to be treated by adequate filtration and chlorination processes. *B. Coli* index shall not exceed 5000 per 100 c.c.

(1) (*b*) Standards for Industrial Water Supply

The requirements of water for industrial use range from high standards approaching those for potable water to very impure water for certain coarser industrial processes. The quality of water necessitates a separate determination in each case of the requirements of the industrial processes involved.

(2) Bathing and Recreational Use

(a) *Standards for Bathing*

(1) *California State Department of Health.* 100 *B. Coli* per 100 c.c.

(2) *New York City Health Department.* 3000 *B. Coli* per 100 c.c.

(3) *Connecticut State Department of Health* has classified outdoor bathing water as follows:

Class	Condition	Average *B. Coli* per 100 c.c.
A	Good	0–50
B	Doubtful	51–500
C	Poor	501–1000
D	Very poor	Over 1000

The Joint Committee on Bathing Places of the Conference of State Sanitary Engineers and A. P. H. A. recommends the use of the above classification.

(4) *Eddy and Greeley* suggest for Boston Harbor a single *B. Coli* index of 1000 per 100 c.c. is a warning that excessive contamination may be present at times, and that an average index in excess of 3000 per 100 c.c. shows that the waters may be dangerous to the public health.

(5) *Winslow and Moxon* for the waters in the vicinity of New Haven, Connecticut, suggest an average of not over 100 *B. Coli* per 100 c.c. with a maximum of not over 1000 per 100 c.c. as a reasonable standard.

(6) *Indiana Standards. Coli-Aerogenes* count shall not exceed 100 per 100 c.c. in more than 50 per cent of the samples, and not more than 1000 per 100 c.c. in any single sample.

(7) *Michigan Stream Control Commission.* 500 *B. Coli* per 100 c.c. stated as free of detrimental sewage pollution, 1000 per 100 c.c. as being suspicious.

A relatively wide range in opinions of sanitary engineers exists concerning desirable bacterial limits for safe bathing, varying from 50 *B. Coli* per 100 c.c. to 3000 per 100 c.c., with a general average of about 1000 per 100 c.c. It would appear that it should be possible to narrow the range of opinion from its present value of 1 to 60 by more detailed investigation.

Very little evidence of standards of waters for boating can be found. It would appear that these should be somewhat less rigid, but should approach those of waters satisfactory for bathing. A question exists as to whether present bacterial standards based on *B. Coli* or *Coli-Aerogenes* numbers can be expected to stand the test of rigid court examination, since they are of the indicative rather than the definite type. As an example of this possibility, a recent Supreme Court of Illinois decision held that rather than being positive proof of contamination, high counts of *B. Coli,* occurring over a long period of time without outbreaks of typhoid fever, might even indicate that a water can be considered to be safe.

(3) Fish and Aquatic Life

In a symposium published by the A. S. C. E. (*Transactions*, 1922) Kenneth Allen states: "Fish life, however, is undoubtedly interfered with (with less than 20 per cent saturation) since it has been sufficiently well demonstrated that most edible varieties will not thrive where the percentage of saturation is under 30 per cent."

Dr. Arthur Lederer and Langdon Pearse report (in *Transactions*, A. S. C. E., 1922) on an extended investigation of the fish question, as follows:

1. Fish life is affected by material in suspension and solution, and the variations thereof.

2. Material in suspension may cause disease by fungus growths or death by mechanical stoppage of the gills or suffocation thereby. The character, size, and quantity of the material must be considered. A careless and continuous handling of fish may induce fungus growth through the abrasion of the slimy, protective coating of the body, thus allowing foreign bodies to adhere.

3. Material in solution includes mineral and organic matter and gases. The investigation covered only dissolved oxygen, which, of the gases in solution, was the most important in this case.

4. For continuous fish life, a content of dissolved oxygen of at least 2 to 3 parts per million is required by practically all the fish used in the investigation.

5. The fish studied may live for very short periods in a content of dissolved oxygen of between one and two parts per million. This provides time for the fish to escape to better conditions, if any are available.

6. English observations, as well as German experiments, indicate that in general 2.5 p.p.m. of dissolved oxygen are about the minimum for fish life and that for continuous thriving fish life more is desirable. In the light of the experiments in America, it appears that many species will live in 2.5 parts per million, but that more is desirable.

7. Sudden changes in the character of the environment are undesirable and may cause the death of the weaker specimens.

8. Of the fish experimented on, their vitality or their relative ability to withstand low contents of dissolved oxygen is roughly in the order designated, as follows, the strongest being listed first, the weakest last: German carp (from Illinois River); catfish and bullhead (from Illinois River); black bass (from Illinois River); yellow perch (from Lake Michigan); and sunfish (from Lake Michigan). The pickerel and golden shiner apparently are to be classed with the sunfish. Further data, however, are desired, as the tests on these two species are not as extended as on the others named.

In perhaps the most complete exposition on the subject, M. M. Ellis, in Special Scientific Report No. 2 for the Bureau of Fisheries, entitled "Water Purity Standards for Fresh-water Fishes," concludes as follows:

(1) Extensive field and laboratory studies of the fresh-water streams of the United States show that general water conditions favorable to, not merely sublethal for, mixed faunae of game and food fishes of the "warm water" types and supporting organisms, present a complex defined by:

(*a*) Dissolved oxygen not less than 5 p.p.m.

(*b*) pH range between 7.0 and 8.5.

(*c*) Ionizable salts as indicated by a conductivity between 150 and 500 mho $\times 10^{-6}$ at 25° C. and in general not exceeding 1000 mho $\times 10^{-6}$ at 25° C.

(*d*) Ammonia not exceeding 1.5 p.p.m.

(*e*) Suspensoids of a hardness of one or greater, so finely divided that they will pass through a 1000-mesh (to the inch) screen; and so diluted that the resultant turbidity would not reduce the millionth intensity depth for light penetration to less than 5 meters.

Elaborating on conclusion (1) in a report of the National Resources Committee, the following statement is made.

(*a*) Dissolved oxygen not less than 5 p.p.m. (lethal levels of dissolved oxygen vary from 0.56 p.p.m. for goldfish to 3.4 p.p.m. at 25° C. for trout. Since respiratory and circulatory compensations, which are distinctly undesirable in fish, begin long before these low levels are reached, the limit given seems to be the lowest value which may be reasonably expected to maintain a varied fish fauna. Cold-water fishes require even a higher dissolved oxygen level).

In *Civil Engineering,* Sept., 1933, Pearse stated that 3 p.p.m. of dissolved oxygen will support fish life.

Black and Phelps, in *Proceedings,* A. S. C. E., March 1926, proposed a standard of 70 per cent saturation of dissolved oxygen for the waters of New York Harbor to avoid detriment to major fish life.

For waters acceptable to the raising of shellfish a generally accepted standard in the past has been 50 *B. Coli* per 100 c.c. However, with the development of the process of chlorinating shellfish before shipment to markets, it is likely that this standard will bear reconsideration in the future.

(4) Agricultural Use

(*a*) *Irrigation*

(1) Septic conditions should not be produced.

(2) State of Colorado has established standard of water for irrigation of not more than 1000 *Coli-Aerogenes* per 100 c.c.

(*b*) *Livestock Watering*

Anthrax and bovine tuberculosis can be contracted by cattle drinking polluted waters. Furthermore, waters in which cattle wade should be sufficiently free of pathogenic bacteria so as to reduce the possibility of contaminating milk by material which is not or cannot be washed out of cracks in udders.

(5) Navigation

A review of the various requirements indicate the following to be desirable minimums.

(*a*) Sludge banks should not be formed.

(*b*) The water shall not contain sufficient hydrogen sulfide so as to affect the paint on boats or maritime structures.

(*c*) The water should not be obnoxious or objectionable from the standpoint of sight or smell.

(*d*) The number of pathogenic organisms shall not be sufficiently high so as to constitute a health menace to those necessarily coming in contact with the water.

In his testimony in the Lake Michigan Diversion Case, Harrison P. Eddy set up what he considered reasonable standards from the viewpoint of navigation, as follows:

1. The water should be practically free from visible suspended particles of sewage matter coming from sewage treatment plants.
2. The water should be practically free from oil, grease, color, and suspended matter.
3. The water should not be obnoxious or offensive to, or injuriously affect the health of, passengers and persons employed on vessels or other property used in connection with navigation.
4. The water should not create odors of putrefaction or organic matter.
5. The waters should not be of such composition as to result in an excessive growth of water plants.
6. The water should not cause discoloration of paint on, or otherwise injure, vessels and equipment or other property employed in connection with navigation.
7. The water should contain at least 3 p.p.m. of dissolved oxygen.

(6) Prevention of Nuisance

The early type of standards related to dilution requirements. Thus, in 1887, Herring concluded that to prevent nuisances in the Chicago Drainage Canal 4 c.f.s. per 1000 population be provided.

Stearns, in an investigation for the Massachusetts State Board of Health, concluded that if the flow is less than 2.5 c.f.s. per 1000 inhabitants, an offense would be almost sure to result. With more than 7 c.f.s. per 1000 population, the pollution would be too small to cause any nuisance. In 1902 Goodenough, for the Massachusetts State Board of Health, concluded that with 6 c.f.s. per 1000 population objectionable conditions will result. In every case where flow was less than 3.5 c.f.s. per 1000 persons, objectionable conditions resulted.

Shedd, in 1902, recommended to the Committee on the Charles River Dam 5 c.f.s. per 1000 population. Metcalf and Eddy in "*Sewerage and Sewage Disposal*" state that "dilution factors of 3.5 to 6 per 1000 persons are used as common guides by engineers." The above standards have the common weakness that they do not take into account the various factors which affect the ability of a stream to receive and assimilate pollution. Just as an example, the characteristics of the stream (rapids or backwater above dams) are not considered. Furthermore, early users of such standards completely neglected the effect of industrial wastes.

In order to prevent nuisances it would appear desirable to meet the following general requirements:

(*a*) Remove objects of sewage origin.
(*b*) Remove unsightly color.
(*c*) Remove materials that form sleek.
(*d*) Remove solids so that gas lifting of sludge will not occur.
(*e*) Remove solids so that sludge banks will not occur.
(*f*) Remove sufficient organic and putrescible solids so that there will always be oxygen present. According to Keefer (*Sewage Treatment Works,* page 370) range in opinion is from 25 to 70 per cent saturation of dissolved oxygen.

Allen Hazen, in *Proceedings* A.S.C.E., March, 1926, states that to prevent nuisances 30 to 50 per cent saturation of dissolved oxygen is desirable. He continues: "The essential matter is to provide that at no point shall the water be deprived of all of its dissolved oxygen."

General Discussion of Standards

In consideration of what has already been mentioned concerning the extreme variations in river water analysis from day to day and at various points in the river cross-section, some of the standards recently promulgated border on the ridiculous. As an example, the standards for one large river basin, after providing in considerable detail the necessary degree of treatment and the quality of effluent, go on to require "and furthermore, the discharge of such effluent, after dispersion in the water of the river, shall not cause a reduction of the dissolved oxygen content of such water of *more than five* (5) *per cent.* The aforesaid reduction in dissolved oxygen content shall be determined by the average results obtained from dissolved oxygen tests made upon samples collected on *not less than six* (6) *consecutive days* from points in the river above and below the point or points of effluent discharge." Legally, this is a very fine document, but from a practical standpoint, its authors apparently neglected a consideration of many of the factors which enter into the sampling and analysis of river waters. To expect an accuracy of greater than 5 per cent (and the writers must have done that if they intended to extend to any community any share of the diluting capacity of a stream), knowing that, considering only one element of variation, differences in sampling depth of one to two feet may affect the analytical results obtained by several hundred per cent, is fallacious. And to expect such accuracy on the average of only six days of sampling, realizing that other factors being apparently constant, large variations occur from day to day, is carrying a worthless fallacy too far. This same standard provides that the effluent of any sewage treatment plant shall not contain more than 100 *B. Coli* per 100 c.c. At as high a removal as 99.9 per cent by a complete treatment process, with effluent chlorination, the average effluent would still contain approximately 20,000 per 100 c.c. To meet the particular standards referred to, the practically impossible continuous destruction of 99.9995 per cent of *Coli Aerogenes* would be required.

Too often, as in the case referred to, where severe pollution conditions existed for years, some group or groups will arbitrarily establish very rigid standards expecting a stream to be transformed overnight from a foul condition tolerated and condoned for decades to one of pristine purity. The stream did not reach a grossly polluted stage in a year, or even in a decade, but gradually became worse as municipalities and industries grew, and therefore, to be logical and consistent, standards for a particular stream should be gradually raised over a period of time as its increased uses, which apparently were previously restricted proportional to the severity of pollution,

justify. As expressed by one sanitary engineer (the source has escaped the writer) commenting on rigid standards: "it is ridiculous to progress from a muddy dirt road to a six lane paved highway in one step."

The author is not one to condone river pollution where it interferes with uses to which a receiving body has been or can potentially be put. He suggests, however, the use of rational bases for the formulation of standards, and above all, suggests to standards formulators that they critically review their proposed requirements to insure accordance with technical accuracy possible with present method of sampling and analysis.

Rate of Destruction of Bacteria in Various Rivers

In Table X data are shown, for winter and summer conditions, on the destructions of *B. Coli* and *Coli Aerogenes* organisms in various rivers, as related to the hours of river flow time below the point of maximum concentration of bacteria. The difference between summer and winter conditions is interesting. For example, at 50 hours flow

Table X.—*Effect of Time and Temperature on the Per Cent Destruction of B. Coli and Coli-Aerogenes for Various Rivers*

Hours of River Flow Time from Point of Maximum Concentration	Upper Illinois River (1)	Lower Illinois River (1)	Ohio River (1)	Mississippi River		
				1926 (2)	1935–1939 (3)	Average
Winter Conditions						
0	0	0	0	0	0	0
25	53	62	70	86	70	68.2
50	75	80	88	91.5	81	83.2
75	85	86	93	94	86	88.8
100	90.5	91	95	95.5	89	90.2
150	95.3	94.5	98	96.5	94	95.6
Temperature	1° C.	1° C.	7° C.	0° C.	0° C.	1.8° C.
Summer Conditions						
0	0	0	0	0	0	0
25	89.0	91.0	65.0	95.0	85.0	85.0
50	95.9	96.3	88.0	97.0	95.0	94.5
75	98.1	97.2	96.0	98.3	98.9	97.7
100	99.1	97.5	98.7	98.7	99.7	98.7
150	99.8	—	99.7	99.2	99.9	99.7
Temperature	25° C.	25° C.	21° C.	21° C.	25.5° C.	23.5° C.

(1) Results published by U. S. Public Health Service, *B. Coli.*
(2) Results published by U. S. Public Health Service, *Coli-Aerogenes.*
(3) Minneapolis-Saint Paul Sanitary District, *Coli-Aerogenes.*

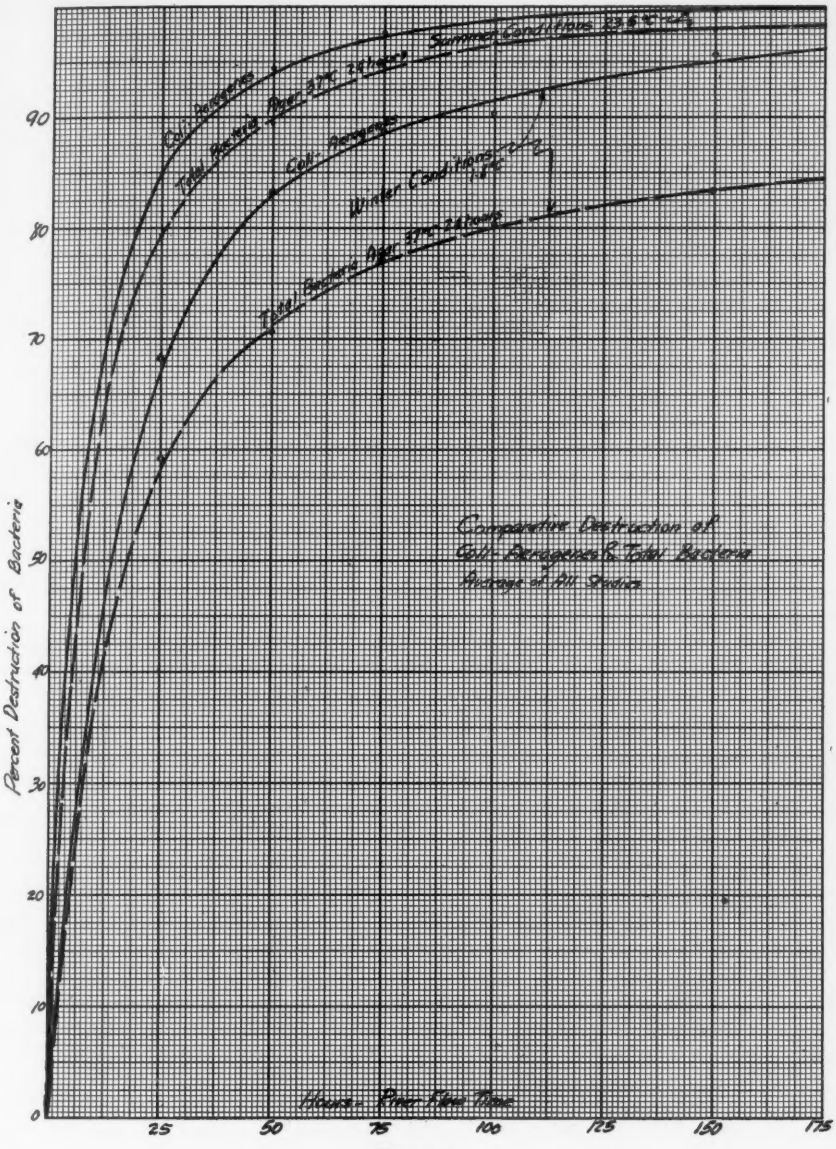

CHART 4.

time, under winter conditions the average of all the data indicates 83.2 per cent destruction of bacteria, whereas, under summer conditions for the same period of time, the destruction is 94.5 per cent. Likewise, at 100 hours, destruction under winter conditions is only 90.2 per cent as compared with 98.7 per cent under summer conditions. Similar data are shown graphically in Chart 4, which includes as well the de-

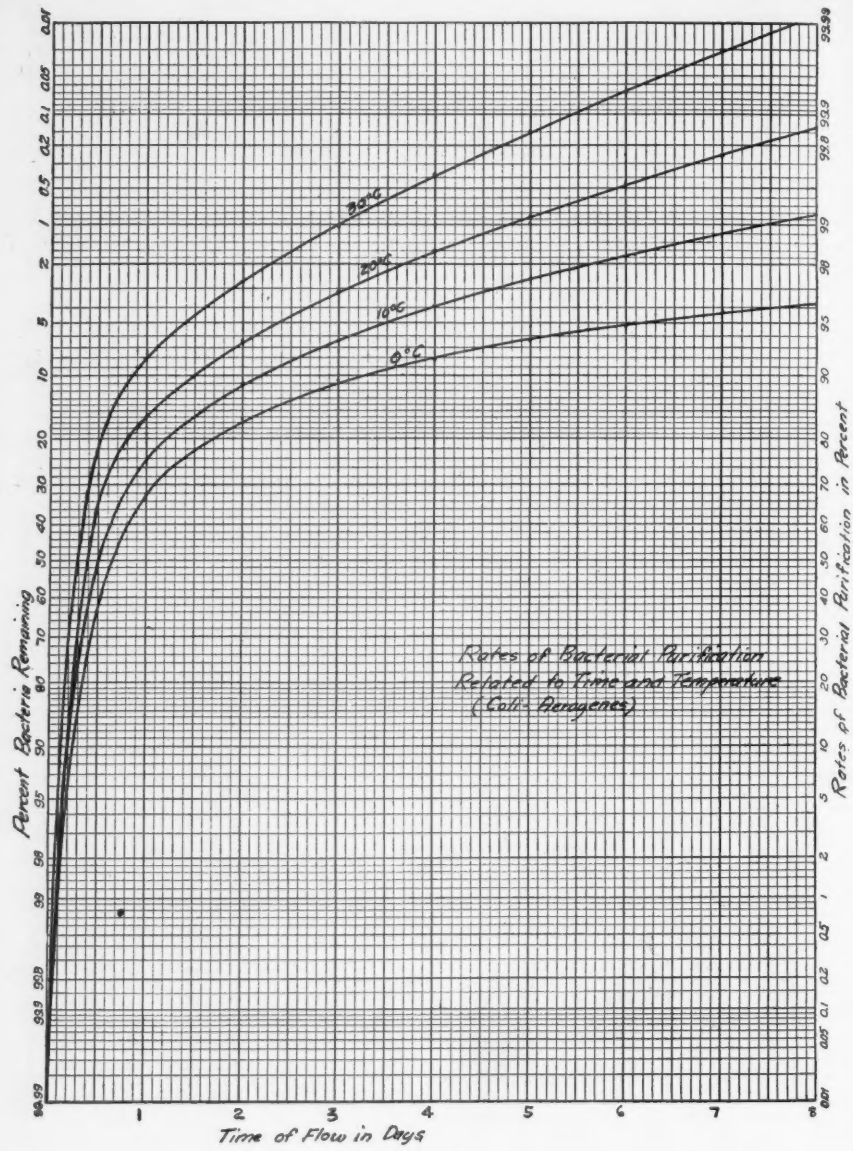

CHART 5.

struction of total bacteria. In Chart 5 the combined effects of temperature and time on the rates of bacterial purification are shown. The different temperature curves have been prepared after a study of the effect of temperature on bacterial purification in the various rivers on which data were available.

Economic Considerations

Realizing the many variations which occur in stream analysis, and having considered the stream standards which we are attempting to meet by present methods of sampling and analysis, it is desired to consider certain economic factors. Sewage treatment, as taxpayers, well realize, costs money. What is a proper balance between the expenditures for this and other health and welfare services, and what is the relation between the epidemiological aspects of sewage treatment and other public health services? What proportion of the funds available, and they are limited, should the sanitary engineer spend on stream pollution abatement, as compared with other health services such as communicable disease control, child mental and industrial hygiene, sanitary inspection, housing for the impoverished, etc. When it is realized that the expenditure of the average city in the United States for all public health work is approximately $1.00 per capita * annually, is it proper to expend $0.50 to $1.00 more per capita for secondary sewage treatment when primary treatment in a particular case would suffice? Wolman states the question very aptly when he says: "The waters bordering on certain municipalities or just below them will permit trout fishing by the people living on the adjacent land, who continue to be deprived of necessary services for the maintenance of health, welfare, and safety." These are all proper questions for the consideration of sanitary engineers.

In Table XI are included data on the construction and total annual costs of sewage treatment per capita, based on a previous paper by the

Table XI.—*Costs of Sewage Treatment per Capita*

Type of Plant	Per Cent Reduction of 5-day B.O.D.	Without Chlorination		With Chlorination	
		Construction Cost/Capita	Total Annl. Charges per Capita	Total Annl. Charges per Capita	Per Cent Destruction of Bacteria
Sedimentation	36	$ 3.25	$ .42	$ .47	98+
Chemical Treatment	70	5.00	.95	1.00	98+
Trickling Filter (Standard)	85	12.00	1.02	1.07	98+
Activated Sludge	92	7.00	1.42	1.47	98+

author. The construction costs of treatment vary from $3.00 to $12.00 per capita, and the total annual costs from $.50 to $1.50 per capita annually, depending on the degree of treatment. Sewage treatment facilities will ultimately be needed by somewhat less than half of the urban population of this country, who do not now have this service. How much should properly be spent for sewage treatment? The same questions stated at the outset of this section bear repetition.

* *Public Health Administration in the U. S.* Smilie, p. 357.

Summary and Conclusion

This paper has included data on some of the variations which occur in the analysis of receiving waters, and has given a resume of some of the standards promulgated for such waters. The primary purpose in the presentation of this paper is the promotion of increased consideration of these various matters during the present lull between the period of rapid expansion with federal assistance just concluded and the era of still greater activity certain to occur in this field in the post-war period.

The author suggests for the consideration of the profession the following subjects:

(1) Thorough investigation of sampling procedures to maintain their accuracy abreast of analytical methods. The need for the development of a sampling device to secure representative composite samples is indicated.

(2) A period of "Stop-Look-and-Listen" in the promulgation of stream standards.

(3) Careful consideration of the balance between funds spent for sewage treatment and other public health and municipal services, with the comparison of benefits in health and welfare of the citizenry ever in mind.

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CLASSIFICATION OF INLAND AND SHORE WATERS *

By Warren J. Scott

Director, Bureau of Sanitary Engineering, Connecticut State Department of Health

Introduction

As Chairman of a Subcommittee on Classification of Streams in New England appointed by the Central New England Drainage Basin Committee of the National Resources Planning Board, the writer has been asked to discuss this subject with special reference to the report of this Committee submitted in June, 1941. The Committee consisted of sanitary engineers from all of the New England state health departments and representatives of other state and Federal agencies. Professor Gordon M. Fair of Harvard University, consultant for the National Resources Planning Board, acted as consultant for the committee in the preparation of its report. The personnel of the committee was as follows:

Edward L. Bike, State Supervisor, Recreation Study, U. S. National Park Service, Boston, Mass.
Lt. Col. J. S. Bragdon, District Engineer, U. S. Engineer Office, Providence, Rhode Island.
E. W. Campbell, Director, Division of Sanitary Engineering, Main Department of Health.
W. C. Herrington, U. S. Fish and Wildlife Service, Department of the Interior, Cambridge, Mass.
C. D. Howard, Chief, Division of Chemistry and Sanitation, New Hampshire State Board of Health.
Eskil C. Johnson, Sanitary Engineer, Sewage & Shellfish Section, Rhode Island State Department of Health.
Dr. C. C. Pierce, U. S. Public Health Service, New York City.
Philip Shutler, Director, Vermont State Planning Board.
Edward L. Tracy, Sanitary Engineer, Vermont State Board of Health.
Herbert E. Warfel, Biologist, New Hampshire Fish and Game Commission.
Arthur D. Weston, Chief Engineer, Massachusetts Department of Public Health.
Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, *Chairman.*

The appointment of this Committee occurred as an aftermath of discussions as to recreational use of waters and protection of fish life in New England, it having become evident that more exact definition of aims and accomplishments in a pollution abatement program was needed. As examples, recreational waters suitable for boating and fish-

* Presented at the Annual Meeting of the New England Sewage Works Association, Boston, Massachusetts, May 27–28, 1942.

ing may not be safe for bathing. Water inhabited by many types of fish life may not be usable for cultivation of market shellfish.

This paper embodies the recommendations in the report with some discussion of certain applications to date of procedures recommended in the report, and comparisons with programs in states outside of New England. The report itself is available upon application to the National Resources Planning Board, Federal Building, Boston, Massachusetts.

Classification of Waters According to Highest Use

The Committee endeavored first to classify waters according to their highest use, as follows:

Class A—Waters used as sources of drinking water or for the cultivation of market shellfish.
Class B—Waters used for bathing.
Class C—Waters used for recreational boating, fishing, culture of seed oysters, or industrial supply after treatment.
Class D—Waters used primarily for commercial navigation or transportation of wastes without nuisance.

Waters which would fall in a category below Class D for purpose of description are referred to as Class E without any intent of dignifying Class E waters to the extent of establishing them in future programs. Classifications of waters must take into account present use and proposed use. Therefore, it is frequently necessary to classify some bodies of water in two ways: according to present highest use, and according to potential highest use. The latter must depend upon practical considerations of economy and feasibility of changes as this classification may be predicated upon improvements in existing methods of disposal of sewage or industrial wastes. The effect of combined sanitary and storm water overflows for some of our large sewerage systems in old New England cities and towns presents a practical difficulty, sometimes of major importance, on some watersheds.

Discussion of Waters According to Locale

The Committee cites in its report some observations as to "use" classifications that would frequently be applied to various stretches of stream or shore water, as follows:

1. *Ocean harbors near large sewer outlets.* Such waters would appear to fall for the most part into Class D.

2. *Sea water not far removed from large sewer outlets but so situated that one tide does not carry sewage effluent to the area.* These waters would appear ordinarily to fall into Class C.

3. *Sea water along sparsely populated shores relatively free from pollution, or sea water outside of harbors.* These waters would ordinarily fall into Class A.

4. *Large rivers draining watersheds of large communities.* These waters would appear ordinarily to fall into Class C, although sometimes into Class D.

5. *Inland streams and lakes draining sparsely populated areas.* These waters should fall into Class A or Class B.

6. *Inland streams now receiving considerable pollution but not main carriers of wastes.* These waters may fall into Class C, but by suitable treatment of sewage and industrial wastes they may often be advanced to Class B.

Minimum Quality of Receiving Waters According to Use

It is felt that the following relatively simple basic requirements for compliance with the "use" classifications as suggested by the Committee, have much to commend them, at least for New England conditions, in that they are adaptable to intelligent application without the failing of being too "loose." They are as follows:

	Physical Appearance	Dissolved Oxygen	Bacterial Quality
Class A	Clear	Near saturation	*Better than 50 coliform organisms per 100 ml.
Class B	Clear	Near saturation	*Better than 1000 coliform organisms per 100 ml.
Class C	Free from slick, odors, or visible floating solids	†Adequate for fish life	No set standard
Class D	Free from slick, odors, or visible floating solids	Dissolved oxygen present at all times	No set standard

Note: Waters which now fall below Class D may be referred to as Class E.

* These standards should be considered in connection with sanitary survey data for the body of water in question. The lower limits of compliance with the bacterial standard in Class A represent a minimum standard of raw water quality prior to chlorination for drinking purposes. The lower limits of compliance with the bacterial standard in Class B represent a minimum standard of bathing water quality. In most New England areas, bathing waters are of far better quality than this minimum standard and can be so maintained.

† Although no specific definition of water qualities adequate for fish life in New England is now available, extensive field and laboratory studies of the fresh-water streams of the United States show that general water conditions favorable to, not merely sublethal for, mixed fauna of game and food fishes and supporting organisms present a complex defined by Ellis as follows:

"(*a*) Dissolved oxygen not less than 5 parts per million.

"(*b*) Acidity range between pH 6.5 and 8.5.

"(*c*) Low density of ionizable salts as indicated by a conductivity between 150 and 500 mho $\times 10^{-6}$ at 25° C. and in general not exceeding 2,000 mho $\times 10^{-6}$ at 25° C.

"(*d*) Ammonia not exceeding 1.5 parts per million.

"(*e*) Suspensoids of a hardness of 1 or greater, so finely divided that they will pass through a 1,000 mesh (to the inch) screen; and so diluted that the resultant turbidity would not reduce the millionth intensity depth for light penetration to less than 5 meters."

Sewage Treatment Methods for Various Classifications—Compact Requirements

In reviewing certain pollution abatement compacts that have been drawn up in this country, one is struck by the extent and definiteness of chemical and bacterial standards for effluents discharged from sewage treatment plants. It is true that specific standards frequently in one fell swoop may hurdle many obstacles and accomplish many desirable results. Yet they also sometimes attempt to provide what may be termed "a lazy man's way of getting a quick answer," leading often to decisions based on arbitrariness rather than knowledge and thus frequently eliminating necessary painstaking search for the correct answer to the particular problem.

The framers of these compacts undoubtedly in setting figures for minimum percentage removal of suspended solids from sewage or for minimum percentage removal of biochemical oxygen demand had in mind provisons of certain known types of sewage treatment processes such as sedimentation, trickling filters or activated sludge without mentioning processes by name. This fact has led to certain incongruities. Opinions as to what may be accomplished in percentage removals of solids by sedimentation apparently vary. The Ohio River compact agreement calls for 45 per cent removal of suspended solids, the Delaware River agreement calls for 55 per cent, and the Interstate Compact calls for 60 per cent, all of these figures apparently being set for sedimentation. The last figure is undoubtedly too high for many well designed and operated modern sedimentation plants, but was fixed at a time when mechanically cleaned sedimentation tanks were few in number so that there was limited available experience as to operating results and when fine screens were being widely advocated by promoters with extravagant claims as to 45 or 50 per cent removal of suspended solids. By setting a figure of 60 per cent, fine screens were definitely ruled out in Class A waters by the framers of the Interstate agreement, which was a desirable move, even though the goal was set too high for plain sedimentation as evidenced by more recent experience. In the writer's opinion, the Delaware River figure of 55 per cent is also somewhat high for uniform compliance by good sedimentation plants.

Percentage removal of solids is not altogether a satisfactory criterion because of the widely varying strengths of raw sewage. A removal of 60 per cent of suspended solids from a raw sewage running 200 p.p.m. produces an effluent with 80 p.p.m. of suspended solids whereas a removal of only 50 per cent of suspended solids from a raw sewage running 120 p.p.m. produces an effluent with only 60 p.p.m. of suspended solids. Obviously in such cases, which are in fact commonly met with, a better quality effluent may be discharged with low percentage solids removal on weak sewage than with high percentage solids removal on strong sewage. Another important factor to be considered when one reviews figures for percentage removals of solids is

the manner of sampling. A separate paper in itself might be written on the many inherent difficulties in measuring plant accomplishments due to inaccurate sewage sampling. A prejudiced sampler may collect raw sewage samples so as to affect greatly the final analysis figures one way or the other. Even an unprejudiced sampler is faced with difficulties in getting representative samples. At few plants except the larger ones are 24-hour composite samples collected. Weak night sewage naturally tends to reduce percentage solids removals. Supervisory authorities who bother to *collect* sewage samples in order to provide for sampling by unprejudiced collectors are reluctant to spend the time necessary to permit collection of *composite* samples. This tends to promote the collection of grab samples or at least samples which are collected over such a short period of time that they approach grab samples in being of little or no value. Where composite samples are collected in less than 24-hours some effort is usually made to allow for the lag due to detention. It is unfortunate that in the collection of sewage samples we do not begin to approach the accuracy of the methods that are used to analyze the samples. Studies have produced devices developed to provide more accurate sampling but such devices do not yet have widespread use.

One objection to specifying processes such as sedimentation or activated sludge is that new uncharted processes may develop and may not be provided for whereas by setting figures without naming processes, new processes may automatically be fitted into the requirements depending on their acomplishments. It appears desirable to leave the way clear for responsible agencies to interpret equivalent accomplishments, thus providing for new processes.

The New England Committee had to consider a wide variety of watershed conditions and did not attempt to set too hard and fast rules for the required processes of sewage treatment for any class of water. Although it was believed that dilution must be taken into account, it was agreed that except for special circumstances, sedimentation should constitute the minimum degree of sewage treatment. As an example of special circumstances, it is stated by the Committee that "in the case of deep sea outlets, fine screening or comminution may be adequate if dilution is sufficiently large and the receiving waters fall into Class D."

Regarding secondary treatment, the Committee says: "In many instances where dilution is not great, particularly during periods of low stream flow, the 'use' classification of the stream may dictate that secondary treatment shall be provided by means of chemical precipitation or biological methods such as activated sludge treatment, or filtration through sand filters or trickling filters. This secondary treatment may be seasonal in nature." Governing considerations in the provision of secondary treatment are set forth in the "use" classification previously listed. The Committee further states: "Where use presents a definite public health hazard by the presence or potential

presence of disease-producing organisms in the receiving water, treatment by disinfection to destroy harmful types of organisms may be necessary." The Committee presents the following rough indication of the various types of sewage treatment which *ordinarily* accord with the "use" classification:

Class	Screening or Comminution	Sedimentation	Chemical Precipitation	Biological	Disinfection
A	X	X	—	X	X
B	X	X	X* or	X*	X
C	X	X	X* or	X*	—
D	X or	X	—	—	—

* Treatment by chemical precipitation or biological process may be unnecessary where large dilution is available.

Disposal of Industrial Wastes

The term "industrial wastes" is meant to refer to water-carried wastes of industrial origin. Sometimes these wastes are discharged into public sewers but most frequently they are discharged separately into receiving waters.

When pathogenic organisms are present in industrial wastes, this fact may be of major importance with discharge into Class A or Class B waters. Disinfection or other treatment may be required. Also, industrial wastes may contain materials that create a heavy oxygen demand upon the receiving water, deposit objectionable solids, discolor the water, adversely affect its chemical quality or otherwise render it unfit for the uses set forth in Classes A, B or C. This may require treatment. The Committee states that moderate amounts of industrial wastes may be discharged without extensive treatment in Class D waters, since the principal "use" considerations in this class of waters are commercial navigation and transportation of wastes without nuisance. However, it is pointed out that where industrial wastes interfere with navigation or place such an oxygen demand on the receiving water as to create a nuisance, treatment of industrial wastes in Class D watersheds may be needed. The Committee did not attempt to fix standards for industrial waste discharges—obviously a difficult and uncertain undertaking.

Aims of Committee Report

The Committee, representing as it did the six New England states as well as agencies of the Federal government, was concerned primarily with the interstate aspects of water pollution. However, it was agreed that in presenting certain practical methods of approach to the general pollution problems in the area, the burden should not be placed unfairly on upstream states. It did not appear fair, for example, for

a downstream state to call for high standards of water in the upstream state and then do little in its own area to abate pollution. This brought the Committee to the agreement that valleys should be considered as entities regardless of state lines and that even valleys originating within a state and discharging to salt water in the same state should be a part of the whole district picture. This meant an area approach to the pollution problem with all states participating for all of their areas.

The Committee, in order to promote progress toward cooperative programs for cleaning up interstate streams, submitted the following recommendations:

1. That the National Resources Planning Board request the Governor of each New England state to appoint a state committee for classification of the state's waters in accordance with the classifications proposed in this report, such committees to include official representatives of state agencies concerned with (1) health, (2) water pollution or water conservation, (3) fish and game, and (4) planning, together with a representative of industry.

2. That each New England state committee subsequently confer with neighboring state committees as to an agreement of classification of interstate waters affecting these states.

3. That the New England state committees, for purposes of cooperation in a program of classification of New England interstate waters, submit for review to the New England Drainage Basin Committees of the National Resources Planning Board their findings as to such classifications, this to involve, however, no commitments between states as to the sanitary works needed.

4. That every effort be made by the New England states to establish sampling points in interstate waters for dissolved oxygen and bacteriological tests, such tests to be made with sufficient frequency to permit determination of the quality index of the waters.

Appointment of New England State Committees

Following the presentation of the subcommittee report and favorable action by the Central New England Drainage Basin Committee, the National Resources Board submitted the recommendations to the Governors of the New England states and classification committees have now been appointed in all of the New England states but Rhode Island. As an example of the membership, the writer might cite Connecticut, where His Excellency Governor Hurley has appointed: General Sanford H. Wadhams, Director of the State Water Commission, Mr. Lyle Thorpe of the State Board of Fisheries and Game, Mr. Kenneth Gregg of the State Development Commission, Mr. A. J. Donahue of Stanford, a manufacturer and representative of industry, and the writer as a representative of the State Department of Health. Committees in the other states are made up along similar lines.

Practical Application of Classification Program

The two New England states which to date have probably progressed furthest in interstate discussions are Massachusetts and Connecticut. Three conferences have been held between Mr. Arthur D. Weston, Chief Engineer of the Massachusetts State Department of Health, Mr. W. S. Wise, Sanitary Engineer with the Connecticut State Water Commission, and the writer. At the time of one meeting, members of the two state committees were present.

In the course of these three meetings, the three principal valleys common to the two states were reviewed, viz., the Housatonic River, the Connecticut River, and the Thames River with its Massachusetts tributaries, the Quinebaug River and French River. Various colors were assigned to each "use" classification for designation on maps. Each stream was classified in two ways. On the map of each river valley, the color shown on the left bank of the stream was made to represent the "use" classification of the stream on the basis of present conditions, and the color on the right bank was made to represent the "use" classification on the basis of future planning. It was surprising to find how quickly engineers familiar with the conditions along the rivers could decide on preliminary classifications. As a result of the meetings of the Massachusetts and Connecticut engineers, preliminary classifications were alloted to all of the streams in the three watersheds, with mutual acceptance by the engineers of the two states. True, it was found that it was difficult to locate separating points of dissimilar classifications along some portions of river especially where complicated by entrance of large tributaries. This, however, focused attention on the need for additional sampling points. Sampling programs along rivers have frequently not been too thoughtfully developed, attempting only to secure representative samples from various geographic portions of the watersheds.

The Importance of Anti-Pollution Planning

Even though we exclude from this discussion the natural effect of the war upon national policies, it is nevertheless true that there has been in recent years a trend toward extension of Federal control in the field of water conservation. The old theory that the Federal government is concerned only with navigable waters is rapidly being broken down by court decisions. One danger in the extension of Federal control is that arbitrary policies may be established on a national basis that may not always fully recognize the peculiar, and not always selfish, local interests involved. Some indication of recognition of this fact is that numerous proposed bills for Federal pollution control have contained provisions for Federal cooperation in establishment of interstate compacts.

It is believed that cooperative undertakings by states in various sections of the country to map out programs for pollution control will place national planning on a far sounder basis than otherwise. The

way, of course, has been shown already by such compacts as the Ohio River, Delaware River and the Interstate. The New England program differs in that it is being undertaken with no immediate plan for legal enforcement and it goes beyond the effect of pollution from one state upon another. It should promote the continued cleaning up of our waters with due regard to the local interests and the local needs. Should Federal control be extended, it is felt that the existence of a plan will be given careful consideration by any new enforcement agencies and that such a plan is likely to be used as a guide. Already a great deal of progress in cleaning up pollution has been accomplished in several of the New England states individually.

The war of necessity must lessen the amount of time that can be devoted to extended planning and must delay the building of new sewage treatment plants, but it appears certain that in the era of readjustment after the war, public works construction will be an important part of the program. Planning is, of course, one of the main functions of the National Resources Board; and it is hoped that the New England plan for water classification may go forward as rapidly as practicable so that when the time comes, the basic information will be ready to support projects for new public works and to guide any new attempts at governmental control.

Discussion

By A. D. Weston

Chief Engineer, Mass. State Dept. of Health

There is little to be added to Mr. Scott's very complete paper as to the work of the Central New England Drainage Basin Committee through the Subcommittee, of which Mr. Scott is Chairman, on classification of streams in New England.

The work of this Committee has required many hours of work by its various members and might well form the basis of a general plan to be adopted for the sanitary protection of streams throughout the country as a whole. With information such as that which has been obtained by Mr. Scott's committee relating to all interstate streams, we will be in a better position to determine the type of legislation, if any, which should be enacted by the Federal Government. In recent years numerous petitions have been filed with Congress with a view to controlling stream pollution but in almost all instances this proposed legislation has been mandatory in character and in the absence of information necessary for the classification of such streams most of the proposed legislation would have a destructive rather than a constructive influence. We must not lose sight of the fact that while protection of the public health is of paramount importance industries and municipalities must have an outlet into our streams for the disposal of sewage and industrial wastes.

Mr. Scott's paper might be amplified somewhat as to the general plan of showing not only the present conditions of streams by the use of

colors inserted on maps on the left bank of the stream but also indicating the condition we hope to be obtained by using the same color scheme on the right bank of the stream. The mutual acceptance of this proposed classification by the sanitary engineers of neighboring states will go far towards remedying objectionable conditions in the streams common to these states and will be equally valuable to Federal agencies in their conservation programs. Such information, together with the results of biological surveys, will make it possible for departments of conservation to plan definitely as to stocking of streams with fish life. It will be of assistance to State Planning Boards and Chambers of Commerce interested in building up industrial activities and recreational areas.

Mr. Scott's Committee has laid the foundation for constructive planing work not only for the streams in New England but the entire country. The organization of similar committees should be encouraged and they should continue to function so far as practicable regardless of the present national emergency in order that plans may be quickly and easily formulated for remedial measures when the present emergency has passed. Had such a planned program been carried out in the past in connection with the Androscoggin River in the state of Maine, the objectionable conditions in that stream recently reported might have been avoided.

The writer predicts that after the present war emergency there will be a great demand for public works projects for the relief of unemployment. Projects relating to stream clearance and cleansing should hold an important place in this program. It is to be hoped that all of the states that are responsible in any way for stream pollution will be found to be as cooperative as were the states of Connecticut and Massachusetts in carrying out their part in the classification program of the Subcommittee of the Central New England Drainage Basin Committee of the National Resources Planning Board.

THE OPERATOR'S CORNER

Conducted by W. H. WISELY, Executive Secretary*
Federation of Sewage Works Associations
Box 18 · · Urbana, Illinois

FEDERATION'S THIRD ANNUAL MEETING TO BE A CONFERENCE ON WARTIME SANITATION

In keeping with the times, the Third Annual Meeting of the Federation, scheduled to be held at the Hotel Statler, Cleveland, Ohio, on October 22–24, will emphasize the exchange of information pertinent to the many new problems facing the field due to the conduct of the war. Never before has the need for adequate and efficient sanitation service been more important—never before, in the short space of a year, have so many new difficulties required solution—never before has a national sewage works meeting been more justified.

Procurement of materials and priorities? Civilian defense sanitation? Wartime problems of State Health Departments? Military camp sewage works operation? New phases of plant maintenance and laboratory control? These question marks and many others will be erased by the unusual technical program, listed in detail elsewhere in this issue of the JOURNAL. Speakers will include A. M. Rawn, Louis H. Kessler, J. W. Ellms, Dr. Willem Rudolfs, Arthur S. Bedell, H. E. Babbitt and others. The manufacturers' exhibits will feature significant wartime developments.

Of particular interest to plant operators who are concerned with procurement of operation and maintenance supplies will be the Priorities Clinic, which will function during the entire meeting. Manufacturers' representatives experienced in the practical aspects of procurement procedures will be available for consultation and opportunity will be afforded to discuss the interpretations of certain WPB orders which are applicable to the sewage works field. This service alone may more than justify your attendance.

Secondary to the timely and carefully prepared technical program, yet important to the success of any gathering is the provision for entertainment made by Chairman Haven's hard-working Local Committee. Vacations and relaxation from the daily routine are acknowledged to be necessary in counteracting the strain of these eventful times; the trip and stay in the beautiful city of Cleveland will give you a pleasurable and profitable "furlough" from the daily grind.

An unusual technical program, exhibits, entertainment, inspection

* Also Engineer-Manager, Urbana and Champaign Sanitary District.

trip, outstanding speakers, special wartime services—all of these combine into the Wartime Sanitation Conference!

COME TO CLEVELAND

OCTOBER 22–24, 1942.

EXPERIENCE IN SEPARATE SEDIMENTATION TANK OPERATION

This review of primary sedimentation tank operation experience is based on data and information obtained from sewage treatment works of various types and sizes. The cooperation of the following contributors is gratefully acknowledged:

Benas, B., Supt., Richmond–Sunset Plant, San Francisco, California
Christenson, C. W., Chemist and Supt., El Paso, Texas
Damoose, N. G., Director Public Service, Battle Creek, Michigan
Drew, Leland F., Superintendent, Clearwater Florida
Hay, Thos. T., Superintendent, Racine, Wisconsin
Henn, D. E., Superintendent, De Kalb, Illinois
Holtcamp, L., Superintendent, Webster City, Iowa
Honens, R. W., Superintendent, Sterling, Illinois
Mackin, J. C., Superintendent, Madison, Wisconsin
Mathews, W. W., Superintendent, Gary, Indiana
Niles, A. H., Superintendent, Toledo, Ohio
Schriner, P. J., Superintendent, Kankakee, Illinois
Schroepfer, G. J., Chief Engineer, Minneapolis–St. Paul, Minnesota
Sperry, W. A., Superintendent, Aurora, Illinois
Stewart, C. L., Superintendent, Oklahoma City, Oklahoma
Wahlstrom, Carl, Superintendent, La Crosse, Wisconsin
Welch, Dewey, City Engineer, Columbia, Missouri
Wilson, C. T., Superintendent, Waterloo, Iowa
Woodward, E. B., Operator, Parsons, Kansas

General

Separate sedimentation tanks are not encumbered with the operating complexities which create problems at certain other sewage treatment units, but faulty practices in primary tank operation may often be partly or wholly responsible for some of these problems. The apparent simplicity of sedimentation tanks has given rise to some tendency to follow generally prescribed procedures without due consideration of local conditions, and troublesome situations involving sludge digestion, sludge dewatering, supernatant liquor disposition and secondary treatment processes have been the result. Instances are common in which notable improvement in overall plant operation has been effected by modifications in primary sedimentation tank control.

Among the important factors requiring cognizance in operating separate primary tanks are: character of sewage, quantity and nature of solids from secondary treatment processes (where these solids are returned to the primary tank influent), type of sludge collection equipment, methods of sludge treatment, prevailing air temperatures, and the availability of operation personnel. Operation practices employed in the several plants discussed herein are summarized in Table I. A cursory examination of this tabulation reveals quickly that there is a wide variation in practice, yet there will be found to be logical reasoning, based upon actual experience, in support of the seemingly extreme procedures followed. That routine operation measures at separate primary sedimentation tanks should be predicated upon extensive and continuous observation and study of all the factors involved, is an obvious conclusion.

Operation of Sludge Collection Equipment

Intermittent operation of the sludge collection equipment reduces operating time and wear on the equipment, although it is possible that the heavier starting loads on intermittently operated machines may partially offset this advantage. Sludge collectors of the "center-scraper" type are usually operated continuously, which observation is substantiated by Table I where only one of the nine plants representing such equipment is shown to employ intermittent operation. The single exception is Gary, Indiana, where Superintendent Mathews operates the clarifier mechanism about half the time in summer and continuously during the winter. Of the "flight type" sludge collectors represented, opinion appears to be divided as regards continuous vs. intermittent operation.

Where intermittent sludge collector operation is practiced, the procedures at Minneapolis-St. Paul and Kankakee, Illinois, are typical. At the former plant, the collectors are operated two hours before and during sludge withdrawal while at Kankakee they are operated for one hour prior to and during pumping of sludge. At Oklahoma City, sludge is withdrawn from the primary tanks continuously between the hours of 7 A.M. to 11 P.M. each day and the collector mechanisms are operated thirty minutes of each hour during this 14-hour period.

It was found by experience at Racine and La Crosse, Wisconsin, that operating conditions were markedly improved by the adoption of an intermittent instead of a continuous collector mechanism operation schedule. Hay of Racine reports:

> At one time the collecting equipment was all operated continuously. At another time it was operated one hour and stood idle one hour. Since early this year the longitudinal collectors have been operated one hour every two hours and the cross collectors have been operated continuously, which procedure brings the sludge to the sump before it becomes septic and the cross collectors concentrate the sludge to the desired degree. We have been able to get sludge concentrations as high as 15 per cent solids but anything over 10 per cent interferes with the proper operation of the mechanical equipment and pumping of the sludge. Eight per cent solids is used as the maximum for operating pur-

TABLE I.—*Primary Sedimentation Tank Operation Data*

Plant	Type Tanks	Collector Mechanism Operation	Sludge Pumping Data				Raw Sludge Data			Wet Sludge Quantity	
			No. Pumpings Daily	Pumping Rate (G.P.M.)	Pumping Time (Min.)		Type	Per Cent Solids	Per Cent Volatile	Gal. Per M.G. Sewage	Gal. Per Capita Per Day
					Per Pumping	Per Day					
Aurora, Ill.	CS	Cont.	5	40	80	400	P[a]	4.7	71.3	2700	0.37
Battle Creek, Mich.	CS	Cont.	3	50	125	375	P	5.7	81.6	3930	0.35
Clearwater, Fla.	Fl	Cont.	4	75	15	60	P	—	—	3000	0.30
El Paso, Tex.	Flx	Cont.	Cont.[c]	60	18–720	950	P	5.0	82.0	5000	0.50
Kankakee, Ill.	Fl	Int.	5	74	20	100	P	8.6	56.5	3600	0.30
La Crosse, Wisc.	Fl	Int.	2	60	250	500	P[d]	5.0	70.0	1200	0.80
Minn.-St. Paul, Minn.[f]	Flx	Int.	3	210–410[c]	[c]	[c]	P	8.0	65.0	2920	0.40
Oklahoma City, Okla.[e]	Fl	Int.	1	36	840	840	P	6.5	71.5	—	0.20
Racine, Wisc.	Flx	Int.	24	35	20	480	P	6.1	66.2	1570	0.26
Toledo, Ohio[e]	CS	Cont.	3[c]	350[c]	100	300	P	7.1	67.5	3025	0.35
San Francisco, Calif.[b,f]	Flx	Cont.	12	170	25	300	FP	4.0	83.0	6000	0.33
Webster City, Iowa	CS	Cont.	6	40	3	18	P[a]	—	—	2400	0.18
Sterling, Ill.	CS	Cont.	2	70	20	40	FP	6.2	64.0	2620	0.23
De Kalb, Ill.	CS	Cont.	6	35	15–45	105	PH	—	60.0	3690	0.57
Waterloo, Iowa	CS	Cont.	4	—	45	—	FPH	6.3	79.6	[g]	[g]
Columbia, Mo.	CS	Cont.	12	50	12	150	PA	2.4	54.5	4000	0.40
Gary, Ind.	CS	Int.	3	85	120	360	PA	5.4	57.7	7500	1.50
Madison, Wisc.[f]	Fl	Cont.	5	60	—	—	PAH	3.0	72.5	7000	1.00
Parsons, Kansas	Fl	Cont.	24	70	6	144	PA	—	—	6500	3.50

CS—Tanks equipped with "center-scraper" mechanism.
Fl —Tanks equipped with flight type mechanism.
Flx—Tanks equipped with flight type mechanism and cross-collectors.
P —Primary sludge only.
FP—Flocculated primary sludge.
H —Trickling filter humus.
A —Waste activated sludge.

[a] Secondary sludge from trickling filters pumped directly to digesters.
[b] Richmond-Sunset Plant.
[c] See text.
[d] Brewery wastes received.
[e] Sludge drawn by gravity to sludge well.
[f] Sludge thickening tanks used.
[g] Highly variable due to packinghouse waste.

poses to allow for sudden rises due to temporary conditions such as rainfall or digester rest periods.

The experience of Wahlstrom at La Crosse has been quite similar to that at Racine:

When the plant was first put into operation, we operated the flights 24 hours a day and pumped sludge three times daily. When operating in this manner we had floating sludge or "popping" of the hoppers, as we called it. We then began operating the flights for one hour before starting pumping and this method seemed to reduce the floating sludge. We then made a plunger for agitating each hopper during pumping and floating sludge has now been cut to a minimum.

Illustrating the influence of local conditions on primary tank operation procedures, Christenson of El Paso, Texas, describes the difficulties encountered in attempting to change from continuous to intermittent mechanism operation:

It is necessary to operate our sludge collectors constantly due to the septicity of the sewage arriving at the plant. Several attempts have been made to work out an intermittent system of collector operation but all have failed. Invariably, during intermittent operation, sludge will rise to form a thin scum on the sewage surface and at times we were disposing of as much as nine cubic feet of skimmings per million gallons of sewage. Intermittent operation also decreased removal of suspended matter considerably. When running the collectors constantly, we can remove 73 per cent of the suspended solids but with intermittent operation this is reduced to slightly over 65 per cent.

Sludge Withdrawal from Sedimentation Tanks

There are two important objectives to be sought in developing the proper sludge pumping schedule in any plant; first, to effect removal sufficiently often and completely to prevent septicity of the sludge with resultant rising, scum formation and reduction in sedimentation efficiency; and, second, to obtain a sludge of such moisture content that it can be pumped without difficulty, yet will not load the digestion or sludge dewatering units with a considerable volume of excess water. In the latter connection, the problem is nearly always that of attempting to increase the thickness of the sludge to avoid waste of heat, excessive quantities of supernatant, poor quality supernatant and to reduce the moisture content of digested sludge at sludge digestion units. Where digester gas is utilized, particularly for power, uniformity of gas production is important and often can be controlled only by the raw sludge feed, or primary tank pumping procedure. The frequency and length of pumping periods, the rate of sludge pumpage and the collector mechanism operation schedule (discussed previously) must usually be correlated to achieve clean sedimentation tanks and optimum sludge consistency.

In measuring the effectiveness of the sludge withdrawal procedure, it is necessary to take into consideration the type of the sludge (whether it is primary alone or in mixture with waste activated sludge or filter humus) and some of its characteristics, such as the volatile content. Prevailing sewage and air temperatures, industrial wastes and staleness of the sewage received are also of moment. Hence, these factors

must be taken into account when comparing data from other plants, even though the sedimentation tanks are similar in type and equipment.

The data contained in Table I illustrates the trends in effect of the type and character of the sludge on pumping operations. It will be noted that raw sludges of higher solids content are generally possible when the volatile content is low, for instance, as at Kankakee, Minneapolis-St. Paul and Toledo. Sludges of high volatile content, as at Battle Creek, El Paso and the San Francisco Terminal Island plant, are lower in per cent solids. The wet sludge quantity data indicates that 0.25 to 0.50 gallons per capita daily or 2000 to 4000 gallons per million gallons of sewage may generally be produced where primary sludge alone is handled, with as high as 1.0 to 3.5 gallons per capita or about 7500 gallons per m.g. of sewage when primary-waste activated mixtures are involved. There is not sufficient data included on primary sludge-filter humus mixtures to justify any conclusion as to wet sludge quantity trends, however, such mixtures would be expected to produce quantities between the values for primary sludge alone and the primary-waste activated mixtures.

Frequency and Times of Sludge Withdrawal

Of the data contained in Table I, none shows more strikingly the need for studying each individual sedimentation tank installation than the column headed "Number Pumpings Daily." The wide range in practice from the almost continuous withdrawal at El Paso and Oklahoma City to the short, hourly withdrawals at Racine, Wisconsin, and Parsons, Kansas, will be noted. Thirteen of the nineteen plants represented, however, are shown to employ two to six withdrawal periods daily.

It is sometimes possible to follow a very simple pumping schedule with relatively uniform length of pumping periods, as at Clearwater, Florida; Racine, Wisconsin; Kankakee, Illinois; Columbia, Missouri, and Parsons, Kansas. Generally however, some flexibility to meet seasonal or other varying conditions must be exercised. Niles at Toledo schedules a minimum of three pumping periods daily but occasionally finds it necessary to pump as many as seven times daily; packinghouse solids received at Waterloo, Iowa are so irregular in volume that the duration of each of the four daily pumping periods is highly variable; similar inconsistency in pumping time is unavoidable at Battle Creek, Michigan because of the varying moisture content of the accumulated sludge.

Usual practice is to distribute the pumping periods throughout the 24 hours of the day, with at least one pumping each shift. In some small and moderately sized plants, operation personnel is not available during the entire day and pumping schedules must be adjusted accordingly. At De Kalb, Illinois, an automatic time switch operates the sludge pump at 1 P.M., 10 P.M. and 3 A.M. for fifteen minutes each time and the pump is manually operated for 15 to 45 minutes (as found

to be necessary) each morning and evening. This method of operation has proven satisfactory in keeping the primary tank clean, delivering sludge of good solids concentration and in affording uniform digestion tank loading through the day. The automatic switch serves to fill out a complete pumping schedule even though the plant is unattended at night.

The pumping schedules at El Paso and Oklahoma City are of interest in that they are adapted to conditions of high prevailing temperatures and extreme sewage capacity. At El Paso, sludge is withdrawn from sedimentation tanks continuously from 10 A.M. to 10 P.M., thirty min-

FIG. 1.—Clarifier room, Racine, Wisconsin.

utes per hour from 10 P.M. to 2 A.M. and eighteen minutes per hour from 2 A.M. to 8 A.M. This almost continuous pumping is required to prevent rising sludge in the tanks. Stewart of Oklahoma City reports that sludge is drawn continuously from 7 A.M. to 11 P.M., an overall period of fourteen hours. Withdrawal here is by gravity to a sludge receiving or storage tank, whence the sludge is pumped to mechanical dewatering units.

At the Richmond-Sunset plant, San Francisco, Benas reports that sludge removal practice may have a direct effect on suspended matter removal by sedimentation units:

When the plant first went into operation some studies were made to determine the efficiency of suspended solid removal in the primary tanks. We found that this percentage was directly correlated with a method of operation of the tanks as applied particularly to sludge removal. If the operation could be such that the sludge is continuously removed without being in the tanks a sufficient time for any septic action to start, it is possible to get an efficiency above eighty per cent of suspended solids removal without the addition of chemicals, with our layout with mixing ahead of sedimentation. However, this required too much time of the operator so that we have standardized on a schedule which gives us removals from seventy to eighty per cent, depending upon the flow and strength of sewage. B.O.D. removals over fifty per cent are obtained on the average.

The duration of each withdrawal or pumping period as indicated in Table I does not take into account the number of tanks (or individual hoppers in each tank) from which sludge is drawn. It is, of course, never advisable to draw simultaneously from more than one sludge sump by means of a single gravity line or sump suction.

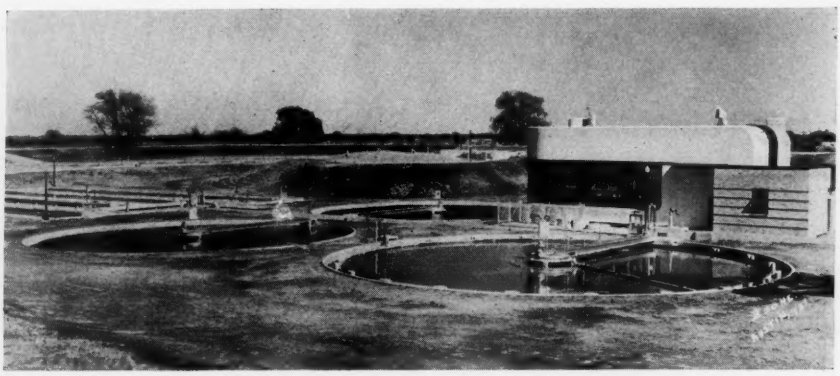


FIG. 2.—View of sedimentation tanks at Austin, Texas.

There is little divergence in practice as to the extent of sludge withdrawal. Usually, cessation of withdrawal is determined by visual examination of the consistency of sludge samples taken at intervals during the pumping period from sampling cocks on the discharge piping. Day by day experience indicates the minimum consistency at which pumpage can be stopped without leaving a sludge blanket of excessive depth. At Columbia, Missouri, Welch reports that an empirical settling test is used, a settled sludge volume of not more than one third the volume of the sample after 15 minutes standing being considered to represent that withdrawal is sufficiently complete. Most of the plants reporting referred to the use of the common "bottle on pole" type of sampler for use in checking the sludge blanket.

Mathews advises regarding practice at Gary, Indiana:

Very rarely do we ever pump a primary tank clean. Usually we try to maintain from six to eighteen inches of sludge blanket at the outside wall of the clarifiers; six inches in summer and eighteen inches in winter. The purpose of this blanket is to keep the sludge compacted as much as possible in the hopper at the center of the tank. We use a pole mounting three bottles spaced at six inch intervals for sounding the sludge in the tanks and measuring the depth of the blanket.

At Racine, Hay finds that it is not possible to correlate the depth of sludge in the sump or hopper with the solids content to yield a definite relationship and states that "the characteristics of the sludge are now followed by analyses of samples taken from the sludge line at the time of pumping." He has found that the residual deposit left in the tanks after withdrawal is necessary to obtain concentration of the solids and that his procedure of pumping frequently and of short duration keeps the sludge from becoming septic.

Temporary storage of sludge in primary sedimentation tanks is sometimes necessary to offset inadequacy in capacity of other plant units. Schriner at Kankakee is troubled by rising sludge at the primaries only in early spring when raw sludge pumpage must be minimized and a heavy blanket carried in order to conserve limited diges-

FIG. 3.—Aerial view of sewage treatment works at Webster City, Iowa.
Courtesy of R. H. Hahne, Webster City, Iowa.

tion capacity. The sludge withdrawal procedure at Toledo must, under certain conditions, be adapted to the digester gas engine installation, as reported by Niles:

> Visual examination of samples usually determines whether withdrawal is complete. However, in the spring of the year, when greater flow and much dilution is present, a raw sludge blanket is carried in the clarifiers in lieu of any gas storage for the operation of our gas engines. When more gas is needed, another well of sludge (about 4,000 gallons) is pumped to the digesters, and the gas from this storage becomes available to the engines in from three to four hours.

Occasionally, Mathews at Gary also finds it necesesary to adjust raw sludge pumping to gas requirements for power. The position of the gas holders in the early morning indicates the demand for such modification.

At Oklahoma City, Stewart has borrowed an idea which originated in the oil fields, for application at the primary tanks:

The way in which we determine the amount of sludge left in the primary tanks or yet to be removed is by using an "oil thief" as used in the oil fields to determine the amount of bottom settlement in tanks. These come in different shapes but the one we use is about 3 in. square and 24 in. long, with a trip bottom that can be closed at any depth at which a sample may be desired.

Withdrawal Rate

The rate at which sludge is drawn from primary tanks is of importance in obtaining sludge of best concentration and proper control of the sludge blanket. Withdrawal at excessive rates will cause water to "pull through" the blanket before sufficient solids have been removed, particularly when the blanket is thin. When withdrawal is by gravity to a sludge receiving well, as at Toledo and Oklahoma City, or to thickening tanks, as at San Francisco, some provision for visual examination is afforded to enable the withdrawal rate to be controlled. Such provision for observation and control is commonly accomplished by "slip or 'swing'" overflow pipes which permit the head on the gravity system to be adjusted to the desired rate of discharge.

Fig. 4.—View of sedimentation unit at Terminal Island Plant, Los Angeles, Calif.

Rates of sludge withdrawal employed in nineteen plants are indicated in Table I. In all but three cases, the rates are 85 g.p.m. or less and of these exceptions, the rates shown for Toledo and San Francisco do not apply to direct withdrawal from the sedimentation tanks but to pumpage from the receiving well and thickening tank, respectively, while Minneapolis-St. Paul has very large sedimentation tanks equipped with flight type longitudinal and cross collectors. Higher rates of sludge pumpage are usually possible from tanks in which cross collector mechanisms are employed because a sludge sump of greater depth and volume is afforded.

In general, rates of direct withdrawal from sedimentation tanks between 35 and 70 gallons per minute appear to be most common.

Operation of Sludge Thickening Tanks

The procedures employed in operating sludge thickening tanks at San Francisco (Richmond-Sunset), Minneapolis-St. Paul and Madison may be of interest. Benas describes practice at the Richmond-Sunset plant as follows:

> Our operation of withdrawal of sludge from our separate sedimentation tanks is somewhat different from the usual procedure as we withdraw first to thickening tanks and then from the thickening tanks to the digester.
>
> Under this method of operation the number of gallons withdrawn is somewhat greater than normally occur. On an average during the summer months we withdraw approximately 8,000 to 9,000 gallons from the sedimentation tanks to the thickening tanks through an arrangement which allows for visual inspection of the sludge withdrawn. The sludge remains in the thickening tanks for approximately 1½ hours, during which time a separation occurs into bottom sludge, supernatant, and scum. The pipe valves are so arranged that the operator can pump the heavy sludge directly to the digester and return the supernatant to the influent channel to the mixing tanks ahead of the sedimentation tanks by throwing in a switch. In other words, one pump and system of piping is on line to the digester and another pump and system of piping is on line to the sedimenattion tank inlet. The operator determines by visual inspection when to operate either system.
>
> Under normal operating conditions we usually pump approximately 6,000 gallons of sludge per million gallons of sludge treated in twelve pumpings of 25 min. each throughout the twenty-four hours, to the digester and return from 40 to 50 per cent of this amount. The sludge varies in per cent solids between 3.5 and 4.5 with a maximum figure of approximately 5. This low solid content is due to the high percentage of volatile, 82 to 84 per cent in the raw sewage, and also to the fact that the sewage is flocculated by mixing ahead of sedimentation.
>
> With our method of operation, not allowing the sludge to remain in the sedimentation tanks for any long period, little trouble is experienced with rising sludge. The only time that any difficulty has been encountered has been directly after rains when there is a tendency to build up a bank of sludge at the sludge hoppers which is difficult to break. This bank is buoyed up by gasification and required breaking by weights or by water pressure. We propose to install an agitator at the sump for this purpose as soon as possible.

At Minneapolis-St. Paul, sludge is pumped from the settling tanks to either of two concentration tanks, care being taken to suspend withdrawal from the tanks when the sludge reaches a solids concentration of about 7 per cent. The determination of the limiting sludge concentration is accomplished empirically by sampling at frequent intervals during the pumping period, weighing of a fixed volume of the sample by the pump operators, and discontinuance of pumping when the weight of the sample reaches a minimum value representing the per cent solids figure desired. The raw sludge is stored in the concentration tanks for one to two days, after which the thickened sludge is carried by bucket conveyors to conditioning units preceding the vacuum filters. Supernatant decanted from the concentration tanks is returned to the raw sewage. The effectiveness of the thickening process is shown by the following annual averages:

Year	Per Cent Solids		pH	
	Raw	Thickened	Raw	Thickened
1938	7.15	9.02	6.2	6.0
1939	7.79	9.13	5.9	5.8
1940	8.07	9.34	5.9	5.8

It has been found that sludges thickened to much over 10 to 12 per cent solids cannot be transferred from the conditioning tanks to the filters with the present equipment, unless diluted by addition of water. Also, to avoid extreme septicity and the resulting increased requirement of conditioning chemicals, it appears desirable at this plant to hold the pH of the thickened sludge above 5.6.

At Madison, Wisconsin, Mackin reports that sludge is drawn from the primary tanks to the thickening units five times daily, with removal from the latter being effected almost continuously at a low rate. A mixture of primary and waste activated sludges is handled and rising sludge is frequently encountered at the thickening tanks, particularly when the activated sludge is bulky. At such times, the rate of withdrawal from the thickeners is increased. Liberal digestion and storage capacity, drying beds and lagoon areas obviate any serious sludge handling problems in this plant.

Sludge Measurement and Sampling

Accurate measurement of primary sludge quantities is extremely valuable as part of the complete operation record. Such measurements are necessary for the computation of digestion and dewatering unit loadings, determination of the solids balance and other purposes. Of the plants represented in this summary of experience, measurement is accomplished by one of the following methods: sludge meter, usually of the venturi type; calibration of the sludge pumps and records of the time of operation; volumetric measurements at a sludge receiving well; or by the tipping bucket combination meter and sampler as developed by Sperry at Aurora, Illinois.

The installations at Minneapolis-St. Paul, La Crosse, Racine and Toledo are typical sludge meter applications. These meters are generally quite satisfactory if given adequate maintenance and when operating in reasonable ranges of sludge concentration and velocity. Niles at Toledo reports that the accuracy of the venturi meters used in that plant for sludge measurement is good for solids concentrations less than 7 per cent but is affected considerably as the per cent solids value increases above that limit.

Typical plants at which sludge quantities are estimated by calibration of the sludge pumps are those at El Paso, Gary, Kankakee and Webster City. The method is not as accurate as would be desirable but will give a fairly good approximation if the pumps are kept free of

clogging materials at suction ports and valves and if the calibration is checked periodically for occasional correction. Christenson at El Paso points out that clogging at positive displacement sludge pumps can be determined quickly by the sound of the pumps.

Examples of the use of a sludge receiving well for volumetric measurement of raw sludge are the installations at Oklahoma City and at Columbia, Missouri. The procedure described by Stewart at Oklahoma City is typical:

> Sludge is drawn from the primary tank into the sludge well which is drained by the sludge pumps. The tank has been calibrated and the volume occupied by sludge drawn to any elevation can be quickly ascertained. During operation of the vacuum filters the sludge pump draws sludge from the well until a low level mark is reached, at which point a float-operated mercoid switch sounds a warning horn to direct the operator's attention to the need for refilling the sludge well.

The tipping bucket sludge meter developed by Sperry and used at Aurora and elsewhere, is described in detail in *This Journal,* **6**, 797 (July, 1934). The meter operates on the volumetric displacement principle and provides for automatic sampling of the sludge flow. Among the advantages claimed are its simplicity of construction and operation and the opportunity afforded for visual examination of the sludge.

Accurate sampling of raw sludge is just as important to solids loading and balance computations as is determination of the quantities, and is usually much more difficult. In almost all plants, samples are taken from the sludge discharge line during withdrawal from the sedimentation tanks, although practice differs somewhat as regards the frequency of portions taken to make up the composite.

At El Paso, a one-pint sample is taken five minutes after the pump is started and two others at 20-min. intervals; a 24-hour composite at Minneapolis-St. Paul comprises one to three gallons and is made up of a sample taken 15 minutes after starting the pump, every 15 minutes during pumping and at the end of pumping, care being taken to flush the sampling pipe before collection of each sample; Hay at Racine takes one 2-quart sample ten minutes after pumping has started, having determined that a maximum of six minutes time is required to move the sludge from the sludge hoppers to the sampling point. Cream cans are used for sludge sample collection at La Crosse (Fig. 5). A convenient sampling arrangement employed at Chicago Heights, Illinois, is described in *This Journal,* **13**, 985 (September, 1941).

Where a sludge receiving well is available, as at Oklahoma City and elsewhere, sludge samples may be dipped at that point, although care should be taken to dip sample portions only while the contents of the well are stirred into a uniform consistency.

Scum Handling and Disposition

Keeping the sewage surface free of floating scum accumulations is an important routine operation item at separate sedimentation tanks. Records of the quantity of such skimmings which may be expected to

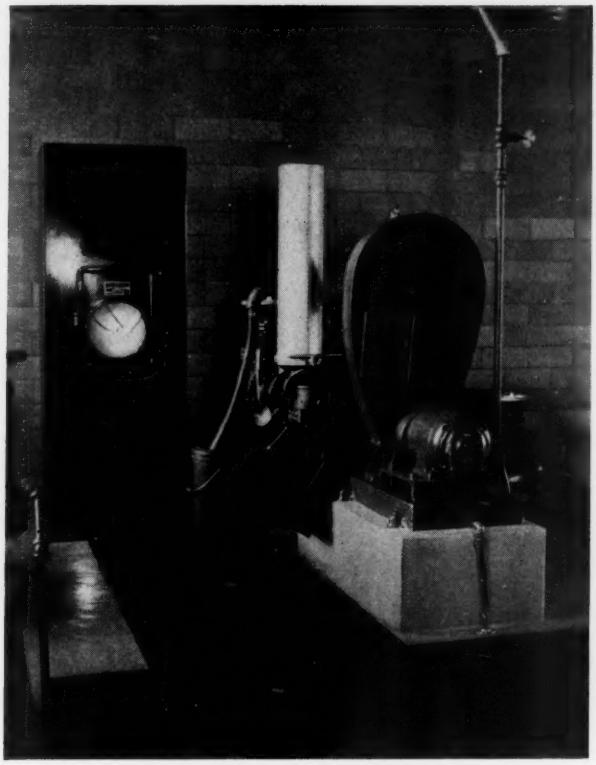


FIG. 5.—One of the two sludge pumps and sludge meter at La Crosse, Wisconsin. Note cream can used for sludge sample collection.

require handling are not universally kept, however, the following average quantities are reported by several contributors to this summary:

Plant	Scum Quantities (Cu. Ft. per M.G.)
Oklahoma City	0.5
Racine	0.5
Madison	1.5
El Paso	4.2
Toledo	3.5–4.7
Minneapolis-St. Paul	3.0–5.0

The range in quantity shown above for Minneapolis-St. Paul includes excess water used to facilitate handling.

SKIMMING METHODS AND DEVICES

Some provision for the removal or, at least, the confinement of scum to a small area of the tank surface is nearly always afforded at mechanically cleaned primary sedimentation tanks. Circular or square tanks

employing the center-scraper type of mechanism are usually fitted with a skimming arm which automatically sweeps the scum into a scum receiving box located at the periphery of the tank. Rectangular units equipped with flight-type sludge collectors are arranged so that the flights move at the sewage surface and concentrate the scum at the outlet end of the tank, where a scum trough is usually located. The scum is then swept into the trough manually (Fig. 6). The scum trough or receiving box is commonly drained by means of a sludge pump connection or by ejector equipment.

FIG. 6.—Skimming primary tanks at Kankakee, Illinois. Note leaf rake used as skimmer.

At Toledo, the skimmings are drawn to a grease concentration manhole whence it is removed with screenings by ejectors. At Minneapolis-St. Paul, mechanical skimming equipment supplements the flight type sludge collectors and ejectors have been found advantageous in handling screenings. The following is extracted from the Sixth Annual Report from the latter plant:

> Automatic skimming mechanisms remove the material from the settling tanks and deposit it in scum troughs from which, with some flushing, it is transported to scum manholes. In the original installation scum was discharged from this manhole to a sump from which the suction of duplex 200 g.p.m. scum pumps was drawn. Difficulties were encountered early because of segregation of materials in this sump and in an effort to correct this condition the suction was connected directly to the pumps. However, suction and discharge lines as well as the pumps themselves became plugged frequently, and in addition to using enormous quantities of transporting water it was necessary to screen out all material retained on three-quarter inch racks. In spite of this, after four months of operation, the scum discharge line cross sectional area has been reduced to one-tenth of its original area by grease incrustations. A number of different methods of handling were considered, of which an ejection method was selected chiefly because of its possibilities of handling relatively dry scum which is an important consideration in connection with final disposal. This method was installed with the result that dry material could be handled without the necessity of removing large material and without attendant plug-ups, which greatly simplified disposal problems. While this problem may appear unimportant from the standpoint of general plant performance, it has greatly reduced the amount of labor required in this portion of the treatment process.

No difficulties were experienced with freezing of sewage in the settling tanks or effluent filters during the winter months. Even with temperatures as low as 25 degrees below zero, sewage temperatures dropped only about 4 degrees Fahrenheit through the plant. Some difficulty was experienced with the automatic skimming mechanisms during cold weather. Heavy frost gathered on moving parts of the equipment with the result that some attachment links were broken. It was found much more economical under these conditions to skim the material into the scum trough by hand, than to attempt to keep the equipment operating.

Walstrohm at La Crosse has found clogging of sludge pumps to be reduced by pumping the skimmings with the sludge as drawn from the tanks, the scum being disposed of in this plant by discharge to the digestion units.

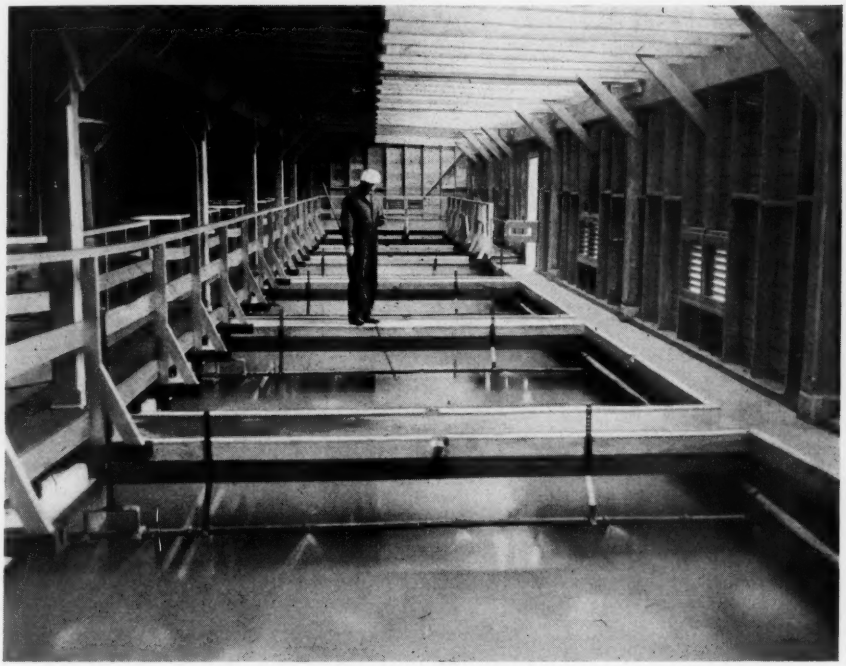


FIG. 7.—Fixed water sprays used for scum concentration at Richmond Sunset Plant, San Francisco, California.

To minimize manual labor, air or water jets are sometimes used to localize the scum accumulation at the scum trough or receiving box. At the Richmond-Sunset plant at San Francisco, the flight-type sludge collectors operate entirely beneath the water surface and are not depended upon at all for skimming, hence water sprays are effectively employed to gather scum at the inlet ends of the tanks (Fig. 7). A hose spray is often used prior to the manual skimming operation to separate settleable particles from the scum and to localize the nonsettleable accumulation. Compressed air is occasionally used to move scum to the skim-

ming trough, as at Battle Creek, Michigan and Shafter, California, which latter installation is pictured in Fig. 8. The "ducking weir" type of scum trough illustrated in Fig. 9 is considered expeditious to the skimming operation.

FIG. 8.—Compressed air scum collector at Shafter, California.

FIG. 9.—"Ducking weir" skimmer in operation at Rochelle, Illinois.

In plants including sludge digestion units, disposition of primary tank sludge is nearly always effected by discharge thereto. Where digestion tank scum may in itself be a problem or where the digestion

process is not used, the sedimentation tank skimmings may be disposed of by other methods, as at Oklahoma City, where this scum is incinerated; Parsons, Kansas, where it is dewatered on the sludge drying beds prior to burial; or by removal to a dump as is done at Toledo, Minneapolis-St. Paul and El Paso. The skimmings are hauled to nearby public dumps at Toledo and El Paso, where coverage is afforded later by grit, street sweepings and ashes. Minneapolis-St. Paul practice is to eject the scum directly to an area in the plant property where it is covered by incinerator ash to prevent nuisance.

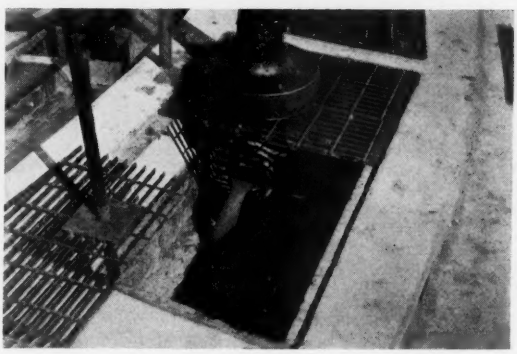


FIG. 10.—Slip pipe employed for control of gravity sludge withdrawal at Pekin, Illinois.

MAINTENANCE OF SEPARATE SEDIMENTATION TANKS

Mechanical.—Among the more important items of mechanical maintenance on clarifier equipment are the following:

1. The electric motors (usually splash-proof or completely enclosed) should be kept properly lubricated at the bearings at all times. Attention at these points is desirable at least three to four times yearly and the bearings and housing should be flushed once a year.

2. Speed reducers require checking once weekly to assure maintenance of proper oil levels and to remove and replace the oil when condensate water has accumulated. Oil should be changed at least twice yearly. If heat develops in the reducer, it may be caused by too high as well as too low an oil level.

3. Life of chain and belt drives will be lengthened by keeping sprockets or pulleys in the best possible alignment, maintaining the correct tension, and prompt replacement of excessively worn or bent shafts, bearings or sprockets. A new chain or belt should never be placed on sprockets or pulley which are excessively worn.

4. All bearings not operating in the sewage require weekly lubrication. Ordinarily, bearings located underwater do not require lubrication.

5. The tank should be drained for a thorough inspection of the underwater mechanism at least twice yearly or more frequently if the manu-

facturer recommends. At such times the metal plows or wood flights should be checked carefully. The metal plows may require straightening, adjustment or replacement; flights which have developed cracks should be replaced and all loose bolts fastening the flights to the chains should be tightened and peened at the end to hold securely.

6. The shear pins are provided to protect the equipment against overload and a broken pin should never be replaced until the cause of the overload is eliminated. Obviously, pins of greater strength than those furnished with the equipment should never be used.

Most sewage works operators appear to adhere strictly to the types of lubricants and lubrication schedules recommended by the manufacturer—always a sound procedure. Local problems may arise, however, at which times the advice of competent lubrication experts should be sought. Damoose at Battle Creek consults lubrication engineers periodically to keep informed as to new developments in special purpose lubricants. To make certain that lubrication is afforded regularly, Hay at Racine schedules Friday of each week as a definite time for such routine attention. At larger plants, such as Toledo, one or more oilers are made responsible for all lubrication work and routine inspection of mechanical equipment.

Sludge collection equipment in sedimentation tanks is relatively simple in construction and operation and serious mechanical difficulties are unusual. The methods of solving two minor mechanical problems at Minneapolis-St. Paul are described in the Eighth Annual Report:

> In 1939, difficulty was experienced due to breakage of links of drive chains on the sludge collection equipment, especially during the winter months. This was attributed by manufacturers to corrosive embrittlement. After a series of experiments with different type chains made of different materials without satisfactory results, adjustable chain tighteners were placed first on one tank and then, after results were demonstrated, on all the settling tank drive chains. This simple expedient has eliminated all difficulty from this source.
>
> During the year 1940 corrective efforts to eliminate wear on the shoes of the collector flights of the settling tanks were made. Prices were secured on new wearing shoes from the various manufacturers of this type of equipment, and from local shops. Because of the relatively high cost of replacement it was felt desirable to experiment with various schemes of welding wear resistant material on the partially worn shoes rather than wait one or two years and completely replace all of the shoes. As a result of this experimenting, all the shoes on the settling tank equipment were stellited with two narrow beads on the worn portion of the shoe. This was done with the shoes in place on the flights at a fraction of the cost of replacement. After almost a year of service very little wear is noticeable.

Painting.—Several of the plants contributing have not been operating sufficiently long to report dependable experience in painting. There is considerable variation in painting practice among the other plants, some indicating that all exposed and underwater mechanism parts are painted annually; others that underwater parts are not painted at all and that exposed parts such as motor and gear housings, hand rails, etc., are painted every one to three years. Mackin at Madison finds that

painting every two or three years is not entirely adequate. Brief statements of painting experience and practice at certain plants follows:

Toledo: "If collectors are kept in constant service and there is no dissolved oxygen in the sewage, painting is not very necessary unless very strong corrosive wastes are present in the sewage. Almost as soon as the collector mechanism is exposed to the air when the tank is drained it starts to rust unless protected by paint. Preparation of the parts for painting is a very slow and expensive process—much more so than the painting alone.

"Our experience has indicated that a tar base rather than an asphaltic base paint is to be preferred. Price is not necessarily an indication of quality—especially so in this type of paint and where there is a wide fluctuation in price. A relatively cheap tar base paint has been the most satisfactory found for this purpose. It was found that thick consistency paint applied in warm weather as heavily as it could be without running, formed the best surface and gave the best protection."

Kankakee: "We have used various types of paints on our sludge collectors and we find that a heavy asphaltic base paint holds up the best. We formerly used an asphalt paint which sold for about $3.00 per gallon, but two years ago we experimented with a paint which sold for about 60 cents per gallon, and we found that this cheap paint was just as good for this purpose as the higher priced paint. We paint the collectors once a year."

Battle Creek: "Originally the collector mechanism was painted with red lead and covered with aluminum which peeled off in sheets after about six months' operation. We wire brushed the whole thing and painted with two coats of asphalt paint which has lasted better than eighteen months so far. We'll know more about this in a few weeks when we again inspect it."

Webster City: "An asphalt base paint is applied to all submerged metals and walls just before winter."

Oklahoma City: "Collectors beneath surface are primed with Tenemic Primer No. 6. Tenemic-Tank black finish coat. Housing—Tenemic No. 6 primer. Aluminum finish coat. Motor and speed reducer—Tenemic No. 6 primer. Rhi-namel finish with bakelite base."

La Crosse: "The sludge collectors have not been painted since the plant was put into operation. The side walls were painted with an asphalt paint and upon inspection we find them in good condition."

San Francisco: "Redwood flights treated with Columbia Wood Preservative."

Racine: "Concrete is painted with bituminous coating below water line, aluminum paint above water line. Driving units and steel work above water level painted with machinery enamel.

"Our clarifiers are roofed over and this produces a difficult problem in protecting steel work above the sewage level such as roof trusses, railings, gratings, etc. The only method found to protect the steel is frequent painting and although over 70 samples of paint have been tested, no paint has been found that is entirely satisfactory in this location. At one time the aluminum paint was carried several inches below the water line in one clarifier and very rapid electrolysis between the paint and the submerged iron and steel took place. This was remedied by carrying the bituminous coating above the water line."

Aurora: "The problem of finding a paint for the underwater mechanism of the clarifiers continues to be unsolved. Early in 1940 two of the clarifiers were painted with a material under the trade name of "Rustex," followed with a coat of special rubber-base paint, which was practically soluble rubber. This clarifier remained in operation for about one year, but on dewatering the results were completely disappointing since there was no vestige left of rubber or the prime coat of "Rustex."

"Due to the grease content of raw sewage and lack of oxygen it is questionable whether the underwater structures of the clarifiers would ever be much damaged while in use. The major damage is in the idle periods when the clarifiers stand empty. It is

questionable, therefore, whether time and effort spent on painting is not a total loss since the complication of the structure makes it impossible to sufficiently clean all portions of the structure to raw metal. This appears to be the only condition under which there is any hope of paint adhering; and then only under the condition of using highly specialized paints as recommended generally by the Aluminum Company of America where bakelite base varnishes with chromium salts as an inhibitor are followed by aluminum pigment paints."

Miscellaneous Sedimentation Tank Problems and Comments

Although digestion tank supernatant is returned to the primary tank influent at several of the plants represented here (Racine, Webster City, Kankakee, Clearwater and others), no serious associated problems are reported. Where the digester supernatant is of high solids content as at Waterloo and Battle Creek (1.5 to 2.5 per cent solids), no effort is made to handle the liquor in the primary tanks. Holtcamp at Webster City suggests that his procedure of returning supernatant continuously at a very low rate of discharge is helpful in minimizing any difficulties traceable to this source. At the San Francisco Richmond-Sunset plant, supernatant liquor from the digesters is handled through the elutriation system in such a manner that the overflow from the elutriation tanks carries practically no solids.

Sludge is not digested at Oklahoma City, but filtrate from the vacuum filters is returned to the primary tank influent. This liquor averages pH 11.5 and appears to be actually beneficial to the sedimentation tanks.

Schriner of Kankakee and Damoose of Battle Creek refer to the importance of keeping primary tank influent conduits free of deposits of septic solids, as an odor control measure. The aerated influent channels at Racine obviate the need for manual attention to this detail. Adequate provision for natural and mechanical ventilation in the buildings housing the sedimentation tanks and sludge handling equipment at San Francisco precludes odor troubles and simplifies interior painting requirements.

Some difficulty with rising sludge appears unavoidable at Battle Creek in the hottest months of the summer. At such times the scum valves are opened and a large volume of water is drawn from the surface of the tanks and returned to the raw sewage wet well. Damoose does not consider this procedure to be entirely satisfactory but points out that it is a practical solution in this plant since the sewage pumps are driven by a gas engine which consistently operates at under-capacity loads.

Pre-chlorination of the raw sewage at Kankakee, Clearwater, Racine and San Francisco is reported effective for odor control and generally beneficial to primary tank operation. Practice at Kankakee is to prechlorinate only during periods of very low flow (Sundays) while chlorine is added continuously at San Francisco at the rate of 30 lbs. per million gallons. Two p.p.m. of chlorine added to the raw sewage is reported by Drew to minimize any tendency for sludge to rise in the primaries at Clearwater.

Christenson of El Paso comments on the ability of the El Paso sepa-

rate sedimentation tanks to maintain high suspended matter removal efficiencies in spite of a heavy overload:

> The plant was designed for about 6 m.g.d. and now we are treating an average of 9.5 m.g.d. Peak rates of 14 m.g.d. are usually encountered for about five hours per day. This gives us an average detention period of around 1.25 hours and during the peak loads it is cut further to less than an hour. In spite of the increased load we are able to obtain a reduction in suspended solids of 72 per cent and B.O.D. reductions of 50 per cent.

Sperry (Aurora) and Benas (San Francisco) have found it worthwhile to investigate short circuiting in the sedimentation units and to provide baffles of special design as a corrective measure. The Aurora experience in this connection is described in *This Journal*, **6**, 531 (May,

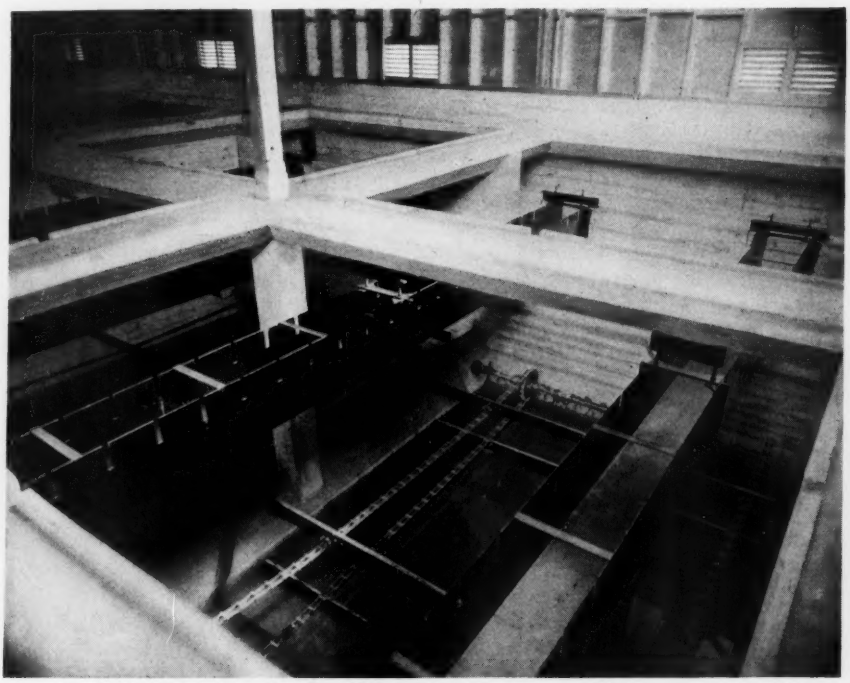


FIG. 11.—Outlet end of primary tanks at Richmond Sunset Plant, San Francisco, California. Note effluent troughs.

1934). Benas has concluded that an effort should be made to prevent discharge at the tank inlet directly into the settling zone and directs attention to the effluent trough design illustrated in Fig. 11, which prevents a high rising velocity by providing for a large take-off area.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Greater Winnipeg Sanitary District (1941)

By D. L. McLean, *Superintendent* and Gordon C. Laidlaw, *Chemist*

Description of Treatment Works

Screening.—No screening is done at the treatment plant as the comminutors act as quarter-inch screens for all sewage coming to the plant.

Main Pumps and Motors.—Total capacity is 87 m.g.d, comprising units of following capacities at a 60 ft. head: two 2.5 m.g.d, one 7 m.g.d., one 15 m.g.d, one 25 m.g.d and one 35 m.g.d.

Primary Sedimentation.—Two Dorr Si-feed Clarifiers—115 ft. diameter with 12 ft. sidewall and 15 ft. centre depth holding 1,000,000 U. S. gal. each and giving a nominal 2-hour detention, removes the suspended solids from the sewage.

Sludge Pumps.—Three screw-feed centrifugal pumps (two of 75 g.p.m. and one of 150 g.p.m. capacity) pump the raw sludge from the clarifiers to the digesters.

Sludge Digestion.—Four digesters each 60 ft. in diameter with 25 ft. sidewall depth are equipped with fixed covers. Two digesters have Dorr Turbo-Mixers and 3-in. diameter steel pipe heating coils with 1050 sq. ft. of heating surface and two digesters have heating coils with 700 sq. ft. heating surface.

The digester covers are insulated and 8 ft. of the sidewalls are insulated in addition to earth embankments which surround these structures. The gas domes on each digester collect the gas for distribution to the boilers and waste gas burners.

Gas Collection.—The gas collected from the digesters is used to heat the buildings and to heat the digesters. The balance is wasted in two 6-in. waste gas burners.

Elutriation.—The digested sludge is elutriated by using effluent as wash water and then settled in two Dorr Type Thickeners 22 ft. in diameter by 10 ft. side depth.

Vacuum Filtration.—The elutriated digested sludge is conditioned by adding chemicals after which, it is dried on two 6 by 8 ft. rotary vacuum filters which produce a sludge cake with 75 per cent or less moisture.

Sludge Storage.—The sludge cake from the vacuum filters is hauled by a steel dump car out on the storage trestle where some 6,000 cu. yd. storage is available. If greater quantities accumulate, the sludge cake is moved to other storage sites on the grounds.

Studies of Odor Development and Control

The Problem.—The flow which reaches the Winnipeg plant is a very heterogeneous aqueous mixture containing waste industrial products

and domestic sewage material. If sufficiently diluted the odor is comparatively light, provided that time for septic action is not permitted. The length of time necessary for septic action to set in will depend on, among other things, the nature of pollution, the temperature of the flow and the extent of bacterial seeding. For most cases in sewage collection, the bacterial seeding is amply profuse. Temperature, however, is partly seasonally and partly industrially controlled.

One typical result of septic action is a production of odoriferous hydrogen sulfide gas. Because this odor is easily subjected to chemical analysis, it is usually used as a gauge of the extent of septic action or of the amount of odor, although the septic odors include quite a variety of odoriferous gases.

In some preliminary tests in the laboratory it was found that samples from packinghouse districts, when allowed to stand at 72° F for twenty-four hours, developed from 2 to 3.5 p.p.m. of total hydrogen sulfide; and average mixed samples from the flow entering the plant would develop in twenty-four hours from 0.5 to 1.5 p.p.m. of sulfide. This would be enough sulfide to produce serious odor conditions.

When the sewage is pumped in a fresh condition, the two most objectionable odors found here were recognized as: a greasy packinghouse odor, and the garlic smell of mercaptan compounds from an oil refinery.

Determination of Sulfides.—There are quite a variety of methods for determining the sulfide content of aqueous solutions. We are interested only in soluble sulfides, so clarified or centrifuged samples must be used. Colorimetric methods cannot be applied successfully to the colored sewage samples. Iodine titrations were tried, but side reactions with the variety of substances in sewage interfered so as to make results meaningless.

Finally, several methods were combined and modified and a fairly exact method was developed. The principle involved was to draw off the sulfide gas from the acidified sample, absorbing it in a suitable solution, where its quantity could be readily estimated. In the first work a stream of air was drawn through the sample and passed through ammoniacal cadmium chloride solution, where the hydrogen sulfide was absorbed. Half an hour of this treatment was not sufficient to withdraw all the sulfide. To improve this, the system was adjusted to aspirate under a very low pressure, drawn by a vacuum pump, the air being admitted in small quantity through a very fine triple jet. Eventually a procedure was adopted that gave almost complete removal of gas in thirty minutes. The cadmium chloride solution in which the sulfide was absorbed was acidified with hydrochloric acid, excess N/10 iodine was added and the excess of iodine was titrated with N/40 thiosulfate. The chief disadvantage of the method was that it took at least three-quarters of an hour per test.

Later in the year an article in the *Sewage Works Journal* by Dr. Richard Pomeroy was reviewed with a view to finding a more simple

and direct test for hydrogen sulfide. The article gave details of a method using a combination of ferric chloride with hydrogen sulfide. The method produced concentrations of dye that were proportional to the hydrogen sulfide concentration of the sample. The amount of dye was estimated by adding standard dye solution to a comparison tube of sample. The first tests showed a 10 per cent error, but later work cut this to a 2 or 3 per cent error for ordinary sample, which was not serious enough to interfere with the results.

Chemistry of Hydrogen Sulfide.—Sulfur may exist in several forms in sewage—metallic sulfides which are insoluble; organic sulfides and proteins containing sulfur, insoluble mineral sulfates which are stable, and as soluble sulfides where there are three possibilities, (S^{--}) ion, (HS^{-}) ion or as dissolved H_2S gas. Odors are related only to the concentration, at a given instant, of the molecular dissolved hydrogen sulfide gas in the solution. We call this the "free sulfide" because it is readily volatile. The "free sulfide" is actually in an equilibrium with the other forms and its concentration is largely a function of the existing pH of the solution.

The ionization constant for this equilibrium was worked out by Dr. Pomeroy in 1935 as 0.91×10^{-7} and corrected in 1941 to 2.0×10^{-7}.

Using this constant, a curve may be plotted giving the percentage of the total soluble sulfides that are in molecular form in relation to the pH of the solution. It shows that at a pH of 5.0, 99.9 per cent of the total soluble sulfides are free sulfide, whereas at a pH of 9.0, only 0.1 per cent are free sulfide.

In one case (Aug. 13) where the pH of the sewage flow through the plant was 7.45, giving 15 per cent of free sulfide, there was 1.2 p.p.m. total soluble sulfide in the flow, and 0.5 p.p.m. of this or 42 per cent was lost in passing through the plant, the greater part presumably to the plant atmosphere.

On another occasion (Aug. 14) where lime was being added to the flow, there was a pH of 8.55, giving 0.05 per cent of free sulfide. Out of a total sulfide of 1.1 p.p.m. there was no measurable amount of sulfide lost in passing through the plant, as the effluent showed the same total sulfide as the influent.

Another case that gives evidence of the pH relationship to odors was on June 24, when the operator in the main building noted a sudden increase in odor, whereupon he took a special sample from the detritor. This sample, when tested, showed a pH 4.6.

It was found generally that 0.15 or more parts per million of free sulfide would cause an odor nuisance about the plant.

Source of Sulfide.—As already mentioned, these sulfides may come from several sources, bacterial actions usually being necessary to liberate them from insoluble compounds. The breakdown of protein as in the rotting of eggs, is a readily available source. In some cases, it is known that mineral sulfates may be broken down to sulfides.

Some work was done in the laboratory to check whether this mineral

reduction was a very pronounced effect at room temperature. Two separate experiments were run in which duplicate samples of detritor sewage were set to brew in the laboratory, one of each set being fortified with 250 p.p.m. of sodium sulfate. Considerable sulfide was produced, but the additional sulfate did not increase the sulfide production in the samples to which it was added. This is not sufficient evidence to make any conclusion on the subject, but it did establish that there are ample protein sources to produce considerable sulfide, irrespective of any additional effects that might, in some cases, be due to mineral sulfate reductions.

Lime Control of Hydrogen Sulfide.—The oldest method of controlling sulfide odors is the addition of lime to raise the pH. Lowering the hydrogen-ion concentration increases the ionization of molecularly dissolved hydrogen sulfide, which decrease in molecular hydrogen sulfide decreases the odor due to sulfide. However, at the same time, lowering the hydrogen-ion concentration decreases the ionization of basic, or amino, odors, which are of the general type of ammonia. This is noted as an immediate increase in these fishy basic odors.

In an actual operational experiment as already mentioned, the pH of the whole flow reaching the plant was raised from 7.6 to 8.5. Sulfide determinations on the influent and effluent of the plant gave the same figures, indicating a negligible amount of hydrogen sulfide being lost to the plant atmosphere. Odor observations confirmed this as far as recognition of hydrogen sulfide, but the character of the basic odors, by their increase in intensity, obscured the sulfide odor results.

Chlorination of Irrigation Water.—In the meantime experiments were being performed in the laboratory on chlorination. At first a solution of chlorine gas in water was used, but later chloride of lime was used as a chlorine source because it was chloride of lime which was to be tried in the first large scale trials.

Plant effluent water was being used for irrigation purposes on the grounds and odors were intensified here because of the water being broken into fine sprays. Chlorination was desirable, but because of the danger of harm to the grass it was imperative that no excess of free chlorine be permitted in the treated water. However, it was felt that considerable improvement could be made with chlorine quantities of one-quarter or one-half of the chlorine demand. (The chlorine dose was sufficient to just leave a trace of free chlorine after 10 minutes contact.)

The chloride of lime contained 33 per cent of available chlorine. The demand of effluent water for this varied from 4 to 8 p.p.m. of chlorine. Chloride of lime solution was added to the irrigation water equivalent to 2 p.p.m. chlorine. This reduced the odor considerably, including sulfide and to some extent amino odors. No indication of residual chlorine was found in samples from the nozzles of the sprays.

Chlorination of Septic Sewage.—As the chloride of lime produced noticeably improved conditions in the irrigation water, the treatment

was extended to the flow through a pumping station following a shutdown, when sulfide odors were very intense. On August 21, Montcalm station was treated in this way. Chloride of lime was added at a rate of 16 p.p.m. chlorine from 8.30 A.M. until 10 A.M. and at 24 p.p.m. chlorine from 10 A.M. to 3.30 P.M. During the day while the treatment was on, the total sulfides reaching the plant were around 0.6 p.p.m. However, that night from 6 P.M. to 8 P.M. the sulfides rose to 1.0 p.p.m. Tests that day were recorded as follows:

Time	pH	Total Soluble Sulfides (p.p.m.)	Free Hydrogen Sulfides (p.p.m.)
9 A.M.	7.70	0.0	0.0
10	8.15	0.0	0.0
11.30	7.75	1.4	0.11
2 P.M.	7.60	0.4	0.04
3	7.55	0.7	0.08
4	7.55	0.7	0.08
5	7.50	0.5	0.07
6	7.45	1.0	0.25
7	7.50	1.1	0.26
8	7.45	1.0	0.25

There was a very noticeable increase in odor when the untreated flow in the evening was reaching the plant. The results of this test were a definite decrease in both sulfide and associated odors, although a fairly strong odor did persist throughout the whole period.

Although septic action can be a major factor in odor production, yet in normal operation the pumping is sufficiently rapid to keep the sewage fairly fresh. Thus during normal operation the mercaptan and packinghouse odors are the main problem. Mercaptan oil can be largely removed from the effluent of an oil refinery before entering the sewer. Packinghouse odor, however, is not very susceptible to chemical treatment, and dilution is its major controlling factor.

In all, the year's work on odors has involved a considerable advance in an understanding of the condition associated with odor production. Study and experimentation has revealed something of the underlying chemistry of odor factors. A suitable test has been developed for sulfides and some information has been gathered on odor control.

Summary of Operation Data

Item	1941 Average	
Population served	260,000	
Equivalent (from raw sewage analyses)	376,700	
Sewage Flow	26.2	m.g.d.
Per capita daily	101	gallons
Meteorological data:		
Mean temperature	37.8	F. degrees
Maximum	80.0	F. degrees
Minimum	−6.0	F. degrees
Total annual precipitation	24.56	inches

Summary of Operation Data—Continued

Item	1941 Average	
Grit removal	2.15	c.f. per m.g.
Sewage Analyses:		
5-Day B.O.D.—raw sewage	301	p.p.m.
Settled effluent	217	p.p.m.
Per cent removal	27.2	
Suspended solids—raw sewage	326	p.p.m.
Settled effluent	138	p.p.m.
Per cent removal	54.6	
Settleable solids—raw sewage	6.6	ml. per l.
Settled effluent	1.8	ml. per l.
Per cent removal	71.1	
Sludge digestion:		
Raw sludge quantity per m.g. sewage	2,120	gallons
Solids content	10.3	%
Volatile content	68	%
pH	5.8	
Digestion temperature	95.5	F. degrees
Digested sludge quantity per m.g. sewage	980	gallons
Solids content	8.1	%
Volatile content	50.9	%
pH	7.4	
Gas production—daily	276,100	c.f.d.
Per lb. dry solids added	5.7	c.f.
Per lb. volatile solids added	8.4	c.f.
Per capita daily	1.06	c.f.
Gas analysis:		
Methane	66.3	%
Carbon dioxide	32.1	%
Oxygen	0.8	%
Gas utilization:		
To boilers	30.2	%
To waste	69.8	%
Sludge dewatering:		
Elutriation system operated—total days	216	
Ratio of wash water to sludge	6.07	
Elutriated sludge solids content	10.4	%
Volatile content	48.4	%
pH	7.2	
Vacuum filtration operated—total days	182	
Quantity wet cake (per operating day)	29	tons per day
Moisture content	68.8	%
Ferric chloride dosage*	2.6	%
Aluminum sulfate dosage*	5.9	%
Filtrate pH	6.7	
Operation costs (sewage treatment only):		
Per m.g. treated	$7.35	
Per capita per year	$0.27	

* Pounds of chemical per 100 pounds dry sludge solids.

District of Columbia (Year Ended June 30, 1941)

By Elwood Johnson, *Superintendent*

Sewage Pumping.—In the year, the first replacement of an impeller and a filler ring were made in one of the main sewage pumps. Because of rapid wear which occurred with the original cast iron impeller and filler rings, repair parts were purchased made of harder materials. The replacement impeller was made of cast steel with tips of stainless steel forming the wearing edge of the impeller welded on. The filter ring was made of nickel cast iron alloy much harder than the original ring.

Use of these hard materials for several months indicates that the rate of erosion of the impeller and filler ring is much less and that the cost of using the hard materials will be lower than that of standard cast iron. Another solution to this problem of abrasion and suggested by the experience of others faced with the problem is the use of rubber on the filler ring face. This approach is being explored to learn which method will be more economical.

Grit Chambers.—Operation of the grit chambers was controlled so that a maximum velocity of one foot per second obtained. For the year, 2,662.2 cu. yd. of grit were removed from the sewage, which amounted to 7.3 cu. yd. per day or 1.82 cu. ft. per m.g. All grit was shipped to the D. C. Penal Institutions, Lorton, Virginia, by rail for disposal.

During the year, intermittent use of the grit collectors was begun to reduce the mechanical wear of this equipment. Previously, high occasional rates of grit removal resulting from irregular operation made this scheme of operation impracticable. By this plan, the collectors and conveyors are operated a total of only 30 to 40 per cent of the time as required and determined by the operator.

The discharge of night soil into a drain in the grit chamber operating room, which was started in May, 1940, continued throughout this year. This drain conducts the night soil with its flushing water to the main plant sewage suction well at the pumping station. This method of night soil discharge has been entirely satisfactory, as flushing water is available and the operating room is continuously ventilated by forced draft. While the quantity of night soil will diminish with time, on July 1, 1941, there remained 1,074 privies in the District of Columbia, all of the pail type. The total on July 1, 1940 was 1,165. A total of 235,050 gal. of night soil was flushed into the drain at the grit chambers leading to the raw sewage suction well.

Sedimentation Tanks.—A great increase in the scum volumes was obtained in the early months of the fiscal year due to the installation of automatic, mechanical skimming instead of the semi-automatic skimmers originally supplied on these tanks.

A total of 14,997 tons of suspended solids were removed by treatment during the year, a mean of 758 lb. per m.g. of sewage. Likewise, 8,899 tons of 5-day B.O.D. were removed by treatment, or 450 lb. per m.g. of

sewage. The corresponding figures for the total or 20-day biochemical oxygen demand are 12,904 tons for the year, or a mean of 652 lb. per m.g. These values indicate the actual pollutional load which the plant withheld from the Potomac River.

Since the 5-day B.O.D. per person daily is usually 0.17 lb. for sanitary sewers and 0.25 for combined sewers, the composite figure for the District might be taken as 0.20 since 40 per cent of the District is still served by combined sewers. This would indicate a contributory population of

$$\frac{168{,}886}{0.20} = 844{,}140 \text{ persons}$$

to the District sewage treatment plant for June, 1941. As the basis of design of the plant was 650,000 persons, it is apparent that the sludge treatment units are carrying a greater load than their design anticipated. This applies to the sludge treatment units only, as the increase has resulted from increased sewage strengths rather than from greatly increased sewage flows. This overload is no cause for immediate concern, but should the growth of Washington continue at a high rate, some means will become necessary to treat the additional solids.

Sludge Treatment.—All solids removed either as sludge or scum by the sedimentation tanks were treated by digestion, elutriation and dewatering.

As in previous years, one of the eight sludge digestion tanks was used as a storage tank and the others provided digestion space.

Of the total gas production of 306.72 million cu. ft., 41.4 per cent was used in the power plant and the remainder was consumed by the waste gas burners. Since 19,476,765 dry pounds of volatile solids were pumped into the digestion tanks during the twelve months, the gas production was 15.7 cu. ft. per lb. volatile solids added to the digesters. The methane content varied from 55.5 to 62.8 per cent and the net heat value from 568.7 to 609.7 B.T.U. per cu. ft.

Sludge elutriation was practiced through the year with use of Potomac River water and counter current elutriation. The overall wash water ratio for the year is one volume of digested sludge to 3.8 volumes of wash water. The actual effect as determined by alkalinity reductions was 7.5 volumes.

The dewatering of digested and elutriated sludge proceeded regularly throughout the year. Of the total sludge cake production of 23,770 tons for the year, 20,063 tons or 84.4 per cent were shipped by rail to the D. C. Penal Institutions at Lorton, Virginia. The remainder was hauled and used by truck farmers, cemeteries and a small amount by the sewage treatment plant grounds.

Power Plant.—Operation of the power plant was stable throughout the year. The 1,200 horsepower sludge gas engine was opened in October, 1940, and May, 1941, for routine inspection. No major servicing or attention was necessary on either occasion. For the year, the engine supplied 88.5 per cent of the electrical energy used by the plant and ran

97.4 per cent of the time. Full advantage was taken of minimum energy purchases, as energy which had to be purchased because of the creation of certain demands was used almost entirely.

Summary of Operation Data

Item	Average (Year ended June 30, 1941)	
Population (estimated connected)	770,000	
Equivalent (by sewage analyses)	844,140	
Sewage Pumped	108.4	m.g.d.
Per capita daily	141	gallons
Power for pumping (per m.g.)	89.3	kw. hrs.
Per m.g. per foot static head	4.63	kw. hrs.
Grit Removal (daily)	7.3	cu. yds.
Per m.g. sewage	1.85	cu. ft.
Solids content	65.3	%
Volatile content	30.1	%
Primary sedimentation tanks:		
Scum removal	6,650	g.p.d.
Specific gravity	0.96	
Solids content	20.5	%
Volatile content	91.8	%
Sludge removal (wet)	1,130	gal. per m.g.
Solids content	7.9	%
Volatile content	66.1	%
Specific gravity	1.02	
pH	5.7	
Fats content (chloroform)	22.6	%
Efficiencies:		
5-Day B.O.D.—influent	171	p.p.m.
Effluent	117	p.p.m.
Removal	32	%
Suspended solids—influent	180	p.p.m.
Effluent	89	p.p.m.
Removal	51	%
Sludge digestion:		
Digestion temperature	94	F. degrees
Digested sludge quantity (per m.g.)	445	gallons
pH	7.5	
Fats content (chloroform)	6.2	%
Alkalinity	3,364	p.p.m.
Supernatant liquor suspended solids	2.06	%
Gas production (per capita daily)	1.1	cu. ft.
Per pound volatile matter added	15.7	cu. ft.
Sludge elutriation:		
Ratio of wash water to sludge	3.8	
Effective wash water ratio (based on alkalinity red.)	7.5	
Character of elutriated sludge:		
Solids content	6.5	%
Volatile content	44.4	%
Specific gravity	1.03	
Alkalinity	450	p.p.m.
Character of elutriate:		
5-Day B.O.D.	574	p.p.m.
Suspended solids	4,211	p.p.m.
Alkalinity	450	p.p.m.

Summary of Operation Data—Continued

Item	Average (Year ended June 30, 1941)	
Sludge dewatering (total days operated)	220	
Dry cake yield (hourly)	5.9	lbs. per sq. ft.
Moisture content of cake	71.1	%
Total dry cake produced	6,862	tons
Filtrate suspended solids	42	p.p.m.
Operation costs:		
Per m.g. treated	$4.39	
Per capita per year	$0.226	

BARK FROM THE DAILY LOG

By John W. Johnson and George E. Symons

*Guest Co-Contributors,**

Works Superintendent and Chief Chemist, Buffalo Sewer Authority, Buffalo, N. Y.

August 2—Inlet baffle of Clarifier 4 was reduced in depth and the bottom edge notched as a part of the plan to study various types of baffle arrangements and their effect on sedimentation.

August 4—Started the erection of a ventilating hood and stack on the by-pass and control chambers, to carry away chlorine smoke produced in the conduits.

August 5—The new sludge pump, re-designed by Mr. Velzy, was installed and has begun operation satisfactorily.

The Smoke Inspector visited the laboratory this morning to discuss our "smoke problem." One landlord has complained that a renter moved out with the complaint that he "could not stand the poisonous fumes of the burning fecal matter." It was explained to the inspector that the "smoke" was fly ash, inert, sterile and of purely mineral composition.

August 8—Operation of three furnaces continuing satisfactorily. Flash dryer on one furnace has been in use now for some six months. The increased life is apparently due to the change in speeds recommended by the manufacturer.

A report was prepared on investigation of odors near the Capital Theatre, on South Park Avenue, caused by the discharge of sulfur water from an air conditioning system into the sewer. Recommended to the chemists of the Republic Steel Co. to add lime solution to their cooling water to neutralize acid condition of Buffalo River. Ran experiments for them to determine the amount required. Conference with the District Health Engineer on industrial pollution of Scajaquada Creek.

August 9—Visited the South Sewage Treatment Plant of Lancaster, Pennsylvania. This is the treatment plant in which experiments were made on chloro-aeration for grease removal. The work had been discontinued. Both ducks and gold fish were inhabiting the secondary tanks. Bulking was in evidence in one of the secondary tanks.

* Although combined here, these entries are from excerpted separate logs kept by Mr. Johnson and Dr. Symons.

August 12—Received the new Royer Sludge Shredder.
Samples collected from the American Brass Co. wastes composited and analyzed for copper, acid and oil.

August 13—Removal of two pre-cast roof slabs in the Incinerator Building, produced definite improvement of the hot spots in the building. Instead of installing a cold air inlet, larger hot air exits will be built, utilizing cupolas on the roof.
The regular Buffalo River survey was made today and from appearances of samples, the stream at South Park Avenue was the worst in recent months. The pH of 2.1 was the lowest observed since 1937.

August 14—General Manager called regarding the program for rat eradication. Assigned Simpson to rat poison distribution.

August 15—Mr. Horbelt of the City Engineers Department of Akron, Ohio visited the plant at the request of T. G. Schaetzle, Superintendent of Treatment of Akron for information on the cost of incineration at Buffalo. He was provided with our best approximate figures. After reviewing data on bacterial results during the past month, it was decided that the chlorine dosage factor should be raised. Chlorine dosage factor is still 40 per cent under what it was for the same month in the previous two years.

August 18—Inspection of the chlorine evaporating equipment indicates that corrective measures need to be taken. Insulating cotton removed from the top showed severe corrosion underneath metal pans.

August 20—Pumping down west wet well this morning. This threw a large and unusual accumulation of sludge on the bar screens. Conditions at sludge control building unchanged; recirculation being carried on.

August 25—Raw sludge heavy. The long awaited Quaker City packing was received, but the packing was not constructed as the original samples. Reporter from the Courier-Express visited the plant to obtain material on story on odd articles that had been screened from the sewage. Gave him information and made a collection of representative materials, such as, balls, tin cans, etc., which were taken from the screens. Two pictures and good write up published.
Complaint received through downtown office of sewer gases. Investigation indicated probable source to be in manhole in the street.

August 27—Miss Rose Centanni, Editor of the Federal Public Health Engineering Abstracts visited the plant and was conducted through the works. Sludge inventory today. Samples indicated top sludge layers were as deep as usual if not more so. High temperatures prevailing throughout tanks and top sludge layers were quite plastic. Little difficulty experienced in sampling.

August 29—Constructing an exhaust head for the west vacuum pump. The manufactured one which had been on trial was too small and was returned to the factory.

September 1—Labor Day. Mr. Bhoota, a native of India and graduate student at M.I.T. for three years visited the Plant upon the advice of Prof. T. R. Camp.

September 2—In the No. 1 furnace ash cyclone, the concrete in the entire bottom of the cone was found completely worn out, so that the metal shell was exposed. It is proposed to regrout this section. Induced draft fan liners must be replaced in this unit. The vapor fan needs replacement. Wear on the flash dryer is not excessive, but the lining at the exit throat is completely gone.
Mr. Ryan of Cuyahoga Falls, Ohio, visited the plant to see our incinerators.

September 4—Discussed corrosion of chlorine evaporators with operators. Possible surface coatings discussed included white lead, asphalt varnish, rubber base paint, chlorinated rubber paint, etc.
Mr. E. J. Smith, Superintendent, and Mr. Lawrence Rice, Consultant of the Niagara Falls Sewage Plant visited the laboratory to discuss plans for a pollution survey.
Simpson placed rat bait poison at various locations in the main building.

September 6—It was reported that an examination of the induced draft fan in No. 3 incinerator disclosed no appreciable wear. The unit has been in operation about two months and on this basis the fan should last six months to a year or more as compared with the previous run of about sixty days. Accordingly, the relocation of the fans on the clean air side of the cyclone appears to be highly successful and worthwhile.

September 8—Scoured the city in an effort to obtain a satisfactory mesh to repair the gunite concrete in the cyclone of No. 1. Lumnite cement was picked up and we expect the haydite to be delivered tomorrow.

September 10—Mr. Kin reported that by raising ferric chloride dosage it was possible to reduce lime dosage to 6 per cent.

September 17—Spent part of day clearing grit deposits from the west wet well. By flushing back through one idle pump and pumping with the second, a great quantity of the material was removed. This was too great for the screening equipment. It broke. Tomorrow we'll pull down west well for inspection and if expedient will remove its excess deposits by hand, as previously.

September 18—Attended conference in General Manager Epstein's office. Discussed industrial waste pollution of Buffalo River.

September 24—Materials for the site feeders for the ferric chloride have been received. The assembly of the two additional feeders is underway this afternoon.

September 25—A windstorm began before noon and increased steadily throughout the afternoon reaching a peak of approximately 60 miles per hour. The wind was southwest, and the Buffalo and Black Rock Harbor were raised well above normal level.

This caused additional pumping at both the outlying pumping stations, and the main pumping station, but no trouble was reported.
Special samples taken at the Pullman Car Shops on Broadway today.

September 26—Solid content of digested sludge has dropped and it is impossible to maintain a three-furnace load. Efforts to increase the load by additional top sludge does not solve the problem due to the increased furnace temperatures.
Dictated a memorandum on sludge conditioning with one filter for three furnaces. Prepared tabulation of cost of sludge incineration. Analyses of oil samples from the American Brass Co. completed.

September 30—Sedimentation tanks 1, 2 and 4 in service. No. 3 out for painting. Installing a connection between suction lines of clarifiers 2 and 3 for greater flexibility of operation.

October 1—Received approximately 100 bricks gratis, made of Haydite and Lumnite cement from John H. Black Co. These are to be used in experiments in patching the bottom of No. 1 Ash Cyclone.

October 6—A large accumulation of leaves from Buffalo's beautiful 300,000 trees were raked off the screenings belts today to be hauled away to the dumps.
Increased difficulty in removing supernatant liquor through supernatant line. Plugging seems to be deposition of calcium carbonate where filtrate liquor enters supernatant line.

October 9, 10 and 11—Attending meeting of Federation of Sewage Works Association at Hotel Pennsylvania, New York City.
At Federation Meeting, besides attending technical sessions, had discussions with Prof. Hodge of the University of West Virginia; Milton Adams, Executive Engineer of the Stream Pollution Control of Michigan; Al Genter of Baltimore; Dr. Mohlman of Chicago; Miss Swope of Waukegan; W. W. Sanderson of the New York Department of Health; Gail Edwards from Wards Island; Professor Hyde of California; Roy Lanphear of Worcester, Mass.; Mr. Wallace, Superintendent of Water and Sewage of Detroit; and Mr. Holmquist of the Department of Health in Albany. Also attended meeting of the Committee of the Federation on Revision of Standard Methods.

October 14—Heavy precipitation today and incoming sewage brought large accumulation of leaves and sticks. It was necessary to put ten men in the screenings department to carry on operations.
Mr. E. H. Ruble of the Municipal Utilities Dept. of Water, Gas and Sewage of Duluth visited the Plant today.

October 15—Completion of hole to the existing well in the plant water extension project was delayed by high water. Mr. Martin of Green Bay, Wisconsin, accompanied by Mr. Holmes of the Worthington Pump Company were conducted through the Plant.

October 16—Attended the annual meeting of the Canadian Institute on

Sewage and Sanitation at Kitchener, Ontario. Presented paper entitled "Laboratory Control of Sewage Treatment Plant Operation."

October 17—An operator put two dewatering pumps in operation to flush out supernatant lines this morning. This caused a back pressure in the water closet of the sludge control building with a consequent mess.

October 20—Limit switch in the chlorine yard tank hoist failed to operate with the result that cable broke; tank was dropped; no damage, except to cable and wiring. Steaming operations were carried on in the supernatant line. In the afternoon acid was added to the filtrate lines and pumps.

October 21—Concrete counter balance was installed on the screen rake wiper in No. 6 screen machine. This has eliminated all the former crash and strain which has occurred on these units. The operation is now smooth and slow and longer life is expected in the air recoil devices.
Mathieson Alkali reported that they removed approximately 5 lb. of material from No. 1 evaporator cylinder—half of which was ferric chloride and the balance chlorine gum. They will return the cylinder after testing.

October 22—Conference on subject of relation of immediate chlorine demand to 15 minute chlorine demand. Study being made to ascertain possibility of controlling chlorine dosage by immediate or two minute chlorine demand to simplify chlorine control operation when sampling and determination of chlorine demand is assigned to operators, instead of samplers.

October 24—Received tabulated list from General Manager showing individuals, type of accidents, and amount of awards on compensation cases from the beginning of operation to date.
Mr. Dagget of the D. W. Haering Co. visited the laboratory to confer on plan for studying boiler water conditioning and steam return line treatment.

October 27—Representative of the American Lubricants Co. visited the plant and examined chlorine evaporators, noting requirements for satisfactory heating medium. If possible, he will suggest a solution which will be non-corrosive, non-vaporizing and give a good rate of heat transfer.
Inspection of brick patch in the bottom of No. 1 ash cyclone indicates that of three bricks used, paving brick gives the best service.

October 29—Computed the weights of various materials that could be used for cyclone liners. Paving brick would overload the structure. Mr. Heasley of John H. Black brought in a sample known as packing house floor brick, similar to quarry tile. It will be tried experimentally.
Proofread galley proof of paper "Disinfection of Sewage Chlorination" which will appear in the next issue of **Sewage Works Journal.** Discussed outline of a paper on a rapid method for determining sludge solids with Mr. Kin who suggested relating "The Sludge Triangle" which was developed for this purpose, to previous work on centrifuge solids. Prepared memorandum on fly and insect control on the basis of replies received from Research Advisory Service.

Sludge inventory today. All tanks continued to have scum layers, representing most of the solids in the tanks. Surface of all scum layers had decreased in temperature.

October 31—Received trimming gravel for filter gallery and began excavation for pipe drainage to take care of low spot in the grass plot north of the Administration Building.

GRIT CHAMBER OPERATION, GRASS ISLAND SEWAGE DISPOSAL SYSTEM, GREENWICH, CONN.

By Paul Martzell, *Chief Operator*

Prior to installation of our grit chambers in 1932, we always had trouble from grit depositing in the trunk line sewers causing rather frequent cloggages. As our grades on the trunk sewer are very flat, 1 ft. per 600 ft., and flow under 1 to 2 ft. head during high tide, it can be seen that grit would very easily deposit and obstruct the flow. In 1932 S. E. Minor & Co., Engineers, Greenwich, Connecticut, were retained to design grit chambers to relieve this condition. Our grit chambers, therefore, are in the streets at the start of the flat grades of our two trunk lines. This, of course, differs from the usual practice of having the grit chambers at the disposal plant, so that when we clean the grit chambers we have to clean them at the sides of two well-traveled streets and keep odor nuisance to a minimum.

Judging by the absence of grit in the raw sludge pumped to the digestor and the elimination of clogging troubles in our flat trunk sewers, our grit chambers have been very effective in fulfilling their intended purpose.

We have two grit chambers, each having two compartments. Weir boards are provided so that one compartment is used for normal flow while the other comes into use automatically during excessive flow. Each compartment is 5 ft. deep at the inlet end, sloping up to 3 ft. 6 in. at the outlet end; length is 29 ft., width is 2 ft. 8 in. Volume of each compartment is 2,500 gal. On the basis of handling our normal flow of 1,000,000 gal. per day through each normal flow compartment, the retention period is approximately 3½ minutes. This is a longer retention than the usual one minute period, hence a considerable amount of organic matter deposits in the chambers and has to be flushed out once a week. Thursday is our regular day for flushing the grit chambers.

For flushing purposes, each compartment has two lines of 1½ in. perforated brass pipe running the length of the compartment. The perforations are ⅛″ dia. holes on 6 in. centers located in pairs at the upper and lower quarter points of the pipe facing towards the center of the compartment. With this arrangement the streams from the two pipes come together and give us very effective sand agitation. Other arrangements were tried but did not prove as effective as that just described.

These pipes are connected to vertical risers which end just below a manhole cover at the inlet end of the grit chamber. For the weekly flushing operation, a fire hose is connected from a convenient fire hydrant to the riser terminal. Flushing water is provided at about 125 lb. pressure.

The idea of flushing the organic matter out of the grit is similar to backwashing a rapid sand filter, the sand being agitated thoroughly but not sufficient to wash it over with the effluent. During the flushing operation, the sewage is kept flowing through the compartment and carries the flushed organic material to the disposal plant. While flushing we poke a two pronged hook through the sand to the bottom of the chamber and fish up large rags, towels and other material and deposit this material into the sewage beyond the grit chamber so that it is carried to the plant and cut up by the comminutor. We have never had clogging of the trunk sewers from this material. Flushing is continued until the water comes through quite clean as can be easily seen from a manhole at the outlet end of the chamber. It usually requires about twenty minutes to flush a compartment. The flushing is regarded as very important because we actually do remove a great deal of organic matter and still leave the grit in the compartment.

Removal of the grit twice a year is not quite as clean a job as flushing. The compartment to be cleaned is first flushed out as above described and the flushing water shut off. The sewage flow is cut off from the compartment to be cleaned by inserting weir boards which divert it to the other compartment. The water above the grit is then pumped out with a gas driven, plunger type pump. Then one man goes into the compartment, shovels the grit into pails, two men above take turns pulling them up and dumping them into a truck. After the grit has been removed, the compartment walls are flushed down clean.

The grit is taken to an earth fill area and quickly filled over. Although the grit is smelly, odors are not serious, being usually confined within 30 or 40 ft. of the work. In this connection, about a dozen years ago we obtained a 50-gal. drum of disinfectant with a strong carbolic odor and still have about 5 gallons left. We usually use about a quart of this per cleaning job, mostly for disinfecting the truck. A little, however, drips from the truck onto the ground. This disinfectant is of considerable help in keeping down odors. I am sorry I cannot tell you the trade name of this liquid because the only mark on the barrel is just the word "disinfectant." We obtained our present stock, however, from the Standard Oil Company.

The meanest part of the job, of course, is shoveling the grit into the pails with flat shovels. The shoveler wears hip boots and usually soon peels downs to his undershirt. Each compartment has four large manhole covers which maintain sufficient ventilation without the use of a blower. We tried a blower one year but the draft caused the shoveler to develop a heavy cold, and he prefers to work without it.

It usually takes two days to clean all four compartments. From 12

to 15 cu. yd. of sand are removed per year. This is approximately 0.5 cu. ft. per million gal. of sewage flow.

As mentioned previously, our grit chambers are doing an excellent job in keeping our trunk sewers clean and they also prevent wear on our sludge pumps.

Acknowledgment is hereby made to Mr. Joseph Doman, Sanitary Engineer, Department of Public Works, Greenwich, Connecticut for assistance in preparing this paper.

A CORRECTION

Captain Lloyd K. Clark, on military leave of absence from his position of Director of the Sanitary Engineering Division of the North Dakota State Department of Health, is determined that his home State shall receive credit for its activities. We are sorry, Captain Clark, for locating Lisbon, *North* Dakota in the wrong State and for not acknowledging the assistance of the *North* Dakota State Department of Health (instead of South Dakota) in connection with Harvey Quam's Basket Screen Hoist described on page 881 of our July, 1942 issue.

GRIT WASHER AND REMOVER

By Nelson M. Fuller

Olean, N. Y., Water Department

The removal of grit at the Olean sewage treatment plant is a very important detail of plant operation. Large quantities are received from storm drainage and from railroad repair shops. Also large amounts of sewage solids settle out in the grit chamber. Former methods of removal by hand, chain hoist and truck, followed by burial, were very disagreeable, being similar to cleaning out a large privy each week. Six man days were required to carry out this operation. The air-lift system now in use washes the grit and disposes of it in thirty minutes. A mechanical conveyor system proposed for the removal of the grit would have cost $5,000. Using scrap materials, and our own welders, the air-lift pumping equipment cost under $100.

The air-lift system was limited in design to the use of air from our own portable air compressor of 105 cu. ft. capacity. This permitted the use of a 6-in. flow pipe. An air-lift pump is simple to construct after the correct size pipe is found which will give a uniform flow without blowing through. The air and water mixture must have a velocity (up-flow) of 10 ft. per second. The foot piece, or air and water mixing device, was designed so that in this case no obstruction to the free flow of grit, small sticks, and rags which sometimes pass the bar screen, could get fouled at the entrance.

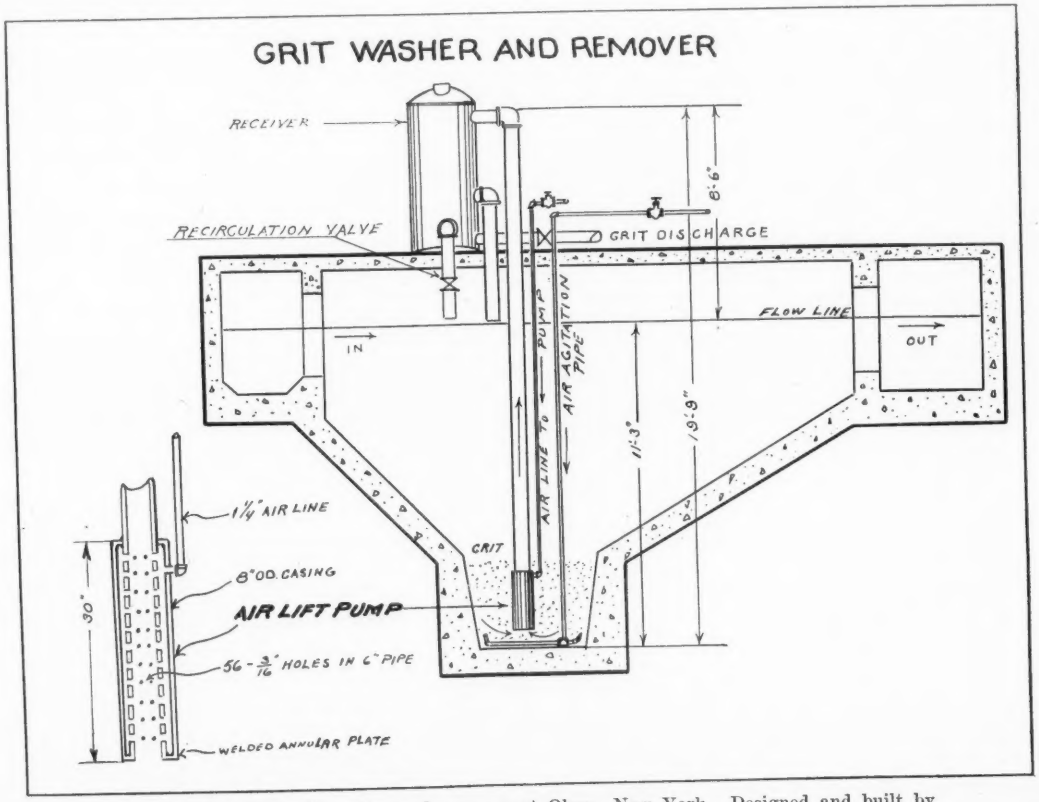


FIG. 2.—Air lift grit washer and remover at Olean, New York. Designed and built by N. M. Fuller, Alfred Mann and Bruce Strong.

The sketch shows a detail of the foot piece which was made by boring 56 holes, each 3/16th in. in diameter, in a 30-in. section of 6-in. pipe. This section of pipe was then placed into a piece of 8-in. pipe and welded at the ends. The 1 1/4-in. air line was attached to the 8-in. casing. A small tank was picked up as junk and was used for the air and water separator, or receiver. It will be observed from the sketch that the grit discharge line from the receiver can be closed and that the grit and solids can be recirculated for washing action in the grit chamber. After a suitable, period of washing, the grit is allowed to settle and the sewage solids which are then in suspension in the grit chamber are flowed into the settling tanks. When this is completed the washed grit is removed by the air-lift pump and discharged to the point of final disposal, which in our case is the Allegany River.

In order to clean out the corners of our grit chamber, air jets have been arranged to agitate the grit in these areas.

While the use of the air-lift system of pumping grit was purely original with us, nevertheless the idea is not new; and in looking up the subject in the literature we have found an excellent paper in *This Journal*, **5**, No. 3, pages 509–522. The author is H. Blunk, Engineer, The Emscher Genossenschaft, Essen, Germany, and the title of his paper is "A Contribution to the Design of Grit Chambers," translated by G. P. Edwards of the Wards Island Sewage Treatment Plant, New York.

CENTRAL STATES OPERATORS DISCUSS WAR PROBLEMS *

By W. D. Hatfield, *Chairman*

Chairman Hatfield: We usually talk about plant operation. However, the war effort now is of primary interest so we might discuss the different phases of the war effort first. I have an outline on the blackboard which we can follow if you wish. The first heading is:

Cooperation with the Office of Civilian Defense

George Martin, *Green Bay, Wis.*: A few months ago I happened to sit in at a meeting at which Major Carey was speaking and he discussed civilian defense and how the various utilities should fit into that picture. I checked up to find out just what other utilities were doing—how they were set up in case of a bombing or some such catastrophe. I found nothing had been done. The idea in Green Bay, I think, was that they should first train fire wardens and air-raid wardens and then get down to the utilities. I thought the utilities were in pretty good shape to take care of themselves. I have tried to imagine what might

* Operators' Breakfast Discussion at Fifteenth Annual Meeting of Central States Sewage Works Association, Minneapolis, Minn., June 19, 1942.

happen if a bomb was dropped in Green Bay, making a hole in the street, possibly in a very busy part of the city where there are gas, light, water and sewage facilities. Nobody would know just what to do. There would be several crews in one particular spot trying to get their particular utility in shape. I thought we should have some sort of an organization set-up so each utility would know where to fit in its part.

In case of an air-raid alarm, no one is allowed on the street unless he is properly identified. We had no identification. Major Carey told us of an incident in which a particular officer was supposed to go to his office when an alarm sounded and take charge of the entire program. Unfortunately, he forgot his arm band and as he stepped out, an air-raid warden got him. He wouldn't let him out of the block. I was afraid that might happen to us. If an officer couldn't get out of his own block, he wouldn't be much good. Finally, about a week ago, the chairman of the committee—the local repair committee—invited all utilities to send their men to a school which will consist of five meetings of 2½ hours each. They are going to give us a little something about bomb and fire protection and a few things like that. They will give us arm bands and at least we will be able to get to the place where we want to go. I do not know whether or not other municipalities have done the same thing. I checked with several and so far none has done any more than that. Only one other did that much.

R. W. Frazier, *Oshkosh, Wis.*: We've started something like Mr. Martin mentioned, but I would like to add another thought along that line. The master plumbers and the journeyman plumbers in Oshkosh have sent a letter to the mayor stating they are willing to cooperate and offering their services to the city government in case of an emergency, furnishing such information as their telephone numbers at the office and at home, amount of equipment they have, trucks, etc. I think that would be a pretty good point to bear in mind when something is developing on getting utilities together. Plumbers will be a great help in such a situation.

W. W. Mathews, *Gary Ind.:* We have mutual aid plans in which an inventory of all water works supplies is put in the superintendent's office. There are seven zones in the state. They ran into the same thing at their meeting—identification. If you didn't have an arm band, you couldn't get to that hole in the street. That's one thing to take up with the Defense Council (Col. Gray). In Indiana, the sewage works men are in on the mutual aid plan with water works men. They have completed an inventory of all sewage and water works supplies which will be invaluable in case of a bombing.

Mr. Martin: Wisconsin has done the same thing. The water works men started the inventory idea. Sewage works people have also started and are now in the process of filling out the same inventories. I was concerned with getting to the hole in the street in case there was a need for it.

DR. M. STARR NICHOLS, *Madison, Wis.*: In connection with this subject, at Madison we organized a defense school for water works men. Emergency protection and sabotage were taken up. The organization of the personnel of each utility, so that each person would know what particular thing he had to do in case of an emergency, was taken up and discussed. The League of Municipalities, the University of Wisconsin and the State Board of Health are behind the school organization. I will say I really think it was quite a sucess as far as meeting merely to organize was concerned. Whether or not the individual operators took any action when they got back is another question.

H. A. RIEDESEL, *Rockford, Ill.:* The O.C.D. has been discussed at some length in Rockford. The difficulties of the utilities getting to the place where a bomb has struck has been pointed out. It seems that the functioning of the various utilities at this point was not completely covered by the setup of organization chart of the O.C.D. and when we discussed it in Rockford there was added what they called a survey committee. This functions in this manner: at the time of the accident or active sabotage or emergency, one of the committeemen is supposed to go to the point where the incident occurred and take charge. Coordination of the effort of different utilities which is necessary to properly repair damage is handled through this individual. I think this is an important point. We could all rush there with arm bands but unless there is somebody there to say just what you should do, there will be confusion.

W. H. CAREY, JR., *Chicago, Ill.:* I have tried to raise some questions with you in order that you can check with the organization that you have already established to find out how it will work. I will try to answer some of these questions by giving you some practical applications of some of the things that have to do with civilian defense.

I do not know how many are familiar with the branch of civilian defense that is known as the Citizens Defense Corps. That is the protection organization and is designed primarily to bring together under one commander all people necessary to operate in any community for its home defense in case of enemy action. This is passive defense. Active defense will be carried on by the Army and Navy against the enemy. If the enemy attacks us, however, there are certain things to do at home that are grouped in passive defense. I am going to talk about two or three of these things you have already raised questions about.

One of the puzzling problems at the moment is the matter of identification. Arrangements have already been made in O.C.D. to identify the members of all repair squads of both public and private utilities. Your regular employees can, without any further training, receive proper identification from the local O.C.D. office. I say that because that is a general order from the O.C.D. in Washington.

There is one thing you should understand in connection with that. Your men are not used to working in shell holes or in the proximity of

fire bombs; they are not used to carrying on their repair activities in the presence of gas or some of the other things which may be present during an enemy attack. There is also the fact that they are not acquainted with operating along with other organizations operating at the same time. When you normally have a break in a sewer main, a single crew from a particular utility goes out to make that repair. Can you imagine what would happen in congested communities—particularly if a large bomb should strike—the number of things that might be brought into play! A broken steam main from the central heating system, sewers broken, gas mains broken, hot wires from the electric power system might be down, telephone cables, Western Union or Postal Telegraph, transportation facilities such as streets and railroad might be damaged—just a whole host of things. If every utility immediately sent repair crews out to that scene—for instance, in a city like Chicago, where an average repair squad consists of a dozen or fifteen people, we might have 300 people trying to work in that one spot. Fires have to be put out, hot wires taken care of, gas mains shut off. You have to get the water main shut off before opening up a sewer. It may become necessary to find an outlet or set up pumps to get rid of water. Then too, don't forget sabotage. You may have on your system a single pump station. You may rely on one power line. You may be relying on stand-by service power and it may be necessary in order to continue, that you have that particular single unit in continuous service. Don't think you are the only one that knows about it. If they decide they want to throw the community into confusion that might be the one spot they want to get at.

During a practice blackout, it was brought to my attention that the repair squads were not properly identified. It became necessary to get out a repair crew. If it had been the local fire department, they have their uniforms and can get around. But the local repair squad that had to go out to cut off power didn't have any identification. Somehow or other they managed to get by. I don't know how, because cruising automobiles of police had been stopping them once every city block, also air-raid wardens asking why and how they happened to be out. Somehow the repair squad got through and to the fire. But if there had been a broken water main or clogged sewer, could the repair squad from that particular department have gotten to the point where they were needed? You must remember, the air-raid warden and auxiliary police or city police have authority to stop your car, tell you to seek shelter and to arrest you if you refuse. And so far, in order to impress the seriousness of the situation on most people, fines have been heavy. It isn't intended to put that on as a measure of enforcement to prevent utilities from performing their regular functions but is an attempt to bring home to the people of our communities the absolute importance of this particular organization.

Identification of your employees is possible. Now, however, it has been recommended that they take some training in gas defense, some in

fire defense, particularly training in handling a fire bomb, and they should take some training in general civilian defense organization. They should also have some specific training from you as their supervisor in the type of work they will happen to encounter in case of enemy action in order that they can be adapted to making speedy and effective repairs. You are accustomed to doing certain things in a certain way. Can you do those things that same way if we have an enemy attack?

One of the questions that you should be able to answer so far as your community is concerned is, "What of community sanitation in case the water supply or local sewerage system fails to function?" Do you know what you are going to do in your community or a portion of your community in case present sanitary facilities are bombed? A mutual assistance program is being organized in most states in the country. In most cases it is in partial stages of organization at the present time. The states in which it is probably best organized in this section of the country are Wisconsin, Illinois and Indiana. Those states are probably the farthest ahead. They were a little more fortunate than some of the others in getting cooperation early in the game. Other states haven't got their organizations quite as far along because at the moment, they didn't see the importance of the program. There are some recent events that are apt to move this program along at the moment. Recent attacks by Japanese on our territory in Alaska, particularly the Aleutian Islands, bring home to us the fact that our strategy should not preclude an attack on the United States itself. That means the entire central west must be activated—a term commonly used by the military—to the problem of civilian defense. This mutual assistance program is just what the term implies—a program for the organization of you as individuals into a group for the purpose of giving assistance to the other individuals in that group in case of necessity.

You heard yesterday a very fine talk on the scarcity of some materials and why we have priorities and I think that brought home to most of us the thought that it will become more and more difficult to get materials for civilian use. We are going to have to rely on stockpiles to produce those materials. We are going to have to rely on one another perhaps with less trained personnel. I venture to say sixty days from now you couldn't hold a meeting and have everyone here today, because several will probably be serving with Uncle Sam in another capacity. The armed forces are going to continue to reach in and take some of your personnel, particularly younger men, for their needs.

(Refers to pamphlet for protection of public water supplies): This bulletin is not ready for general distribution at this time, but it has been produced in limited quantities and has been criticized by state officials and public water supply superintendents. There are some things in here that apply to sewage plant workers. It lists some suggested air-raid protection measures. The following suggestions are for water plants but I think they apply pretty generally to sewage treatment plants, as well:

1. Expand and train repair crews. You *do* need to expand, particularly if we have an enemy attack.

2. Determine assembling points and methods of assembling emergency repair crews. Where are your crews going to meet? You will have to determine that ahead of time.

3. Scatter stores or trucks for emergency repair squads. A single yard may not serve your purpose. It may be put out of commission at the very first attack of the enemy.

4. Availability of additional sources of power supply. This is very important, particularly if you have pumping stations, on which the operation of sewers in certain portions of your city depend.

5. Availability of chlorination equipment. You aren't going to have to worry about the use of chlorination equipment to chlorinate water mains. That is somebody else's job. But you will have to worry about the nuisance that is created by the lack of sanitary facilities and that may be a considerably more serious problem than that of applying H.T.H.

6. Provision of temporary repair parts. Could you go ahead and make temporary repairs on sewers with what you now have in your plant?

7. Adequate information as to location of important points on system so that you can find them during a blackout. Do your men know the difference between various manholes on a street or do they go searching around to separate one manhole from another?

8. Availability of emergency transport for carting water to areas in which service has been disrupted. You wouldn't have to cart water in but you may have to cart sewage away. Are you prepared?

9. Rehearsal of both plant and repair operations in a blackout. It is more difficult to perform operations during a blackout than during normal conditions. Floodlights won't be any good—you're not allowed to use them. You won't be allowed to have other lighting equipment functioning during a blackout. Can you do these emergency jobs during a blackout?

10. Participate in air-raid rehearsals and exercises.

I believe most of you have had opportunity of reviewing the organization chart. In case it becomes necessary for the O. C. D. to take over in your community, it will be under a commander and he will have as his council or advisers men representing police, fire, air-raid wardens, emergency medical service, public works and public utilities. Are you tied into that group? Will you be informed if an air-raid alarm occurs? Will you be told of the possibility of an air-raid alarm so that you can be ready? Most of all, it is necessary that you be identified with the local defense organization. Remember it is on your home front that the battles of civilian defense will be fought, not in my office. We can only assist you in your planning. It wouldn't be possible for me to be in any particular location. You will be there and you will be the man who will

have to run the show so far as watching the facilities of your community are concerned.

W. H. WISELY, *Urbana-Champaign, Illinois:* I believe that it will be evident by this time that the solution to the whole problem of protecting our local utilities—and sewerage systems in particular—boils down to a complete and careful analysis of our own local situation. We have had a lot of bulletins, manuals, and instruction lists made available to us. None of these are worth anything unless applied properly and the only way to apply them properly is to analyze our own systems. First, which are the parts which are the most vulnerable? What parts of the system are essential to give service to the whole town? What parts could you omit in defense arrangements? If a bomb should fall on a main sewer, where would you go to by-pass that section temporarily until repairs could be made? If it is in a very important location you should have a by-pass already constructed and ready to use. We should all keep in mind the fact that certain local conditions are going to be quite different in every community and, while you may be able to apply what comes in a manual in the case of LaCrosse or Gary, it may not have anything to do with Rockford or Minneapolis or some other city.

One other point is the matter of communications during an emergency of this kind. I have heard it stated that in a blackout the telephone company will immediately close about 80 per cent of the telephone services. Be sure your telephones are among the 20 per cent that remain available. Check on it in advance with your local telephone company.

CHAIRMAN HATFIELD: As a final word on this subject, I do feel that we should contact our local Office of Civilian Defense and get something started. Its offices are extremely busy training air-raid wardens and other personnel. I have had to go into their office and discuss the service and I find it is a help to them to have people come to them. I think you would be welcome to go in and ask to be a part of the organization.

MATT KIRN, *Waukegan, Illinois:* May I discuss briefly what we have done at Waukegan? We have sent our crew to different schools for training as wardens, in first aid and fire fighting. At the same time we are part of the city organization, that is, our group comes right in with Waukegan civilian defense in case more people are needed. They are well trained to serve in any capacity in any area of the city, yet we are also organized to protect our particular service.

CHAIRMAN HATFIELD: Decatur is expecting an expansion of population. I feel there might be some members here who are functioning where defense industries are actually in operation. Our second topic pertains to serving such industries, or perhaps, problems of serving the war workers that flock into the area. What are you going to do about trailer camp sanitation? I am expecting some experience in the next six months but really don't know what to expect.

Defense Area Sanitation Problems

J. C. Mackin, *Madison, Wisconsin:* I am in the same position. We expect to be affected, perhaps considerably, perhaps not so considerably, by certain activities in and near Madison. An ultimate population of 15,000 or 20,000 population may be involved. We have contracted to take care of the sewage, which government officials estimate will amount to perhaps 300,000 gallons per day. That is discounted to about 200,000 gallons per day by area engineers.

Perhaps you know Madison houses a rather large University. We have anticipated that the University enrollment, as far as regular students are concerned, will suffer a considerable drop. That may be taken up by government training of soldiers and sailors along particular lines and making use of University facilities, but every week the flow has been dropping off which gives us leeway to take care of extra population. There is another bright side to the picture, as far as summer operations are concerned. When biological processes taper off as they do in the summer time, you do not have a very difficult job of putting out a good effluent. That's the way it is in Madison. Perhaps that is not so in areas where considerable canning is done but we have these reductions in summer flows as a characteristic thing so we are in pretty good condition. However, I am really concerned about next winter. We will have a stronger sewage; that is characteristic of winter time and we are rapidly approaching restrictions. We shall certainly have to get along with what we have. For instance, any additional pumps would have to be of such sizes they would be out of the question to obtain. So we are going to approach this situation with the idea of having to go ahead the best we can.

D. E. Bloodgood: You used the word "contract" to handle this sewage. You actually have a contract with the government?

Mr. Mackin: A contract has been drawn up.

C. C. Larson, *Springfield Illinois:* Do you know whether your sanitary district law permits you to do that? Is it so written or is this an emergency?

Mr. Mackin: The law is an actual order to handle all the sewage from the community; to collect, treat and dispose of it. We can serve that function by contract or any other way.

Mr. Bloodgood: I was interested because in our case our District is limited. Our lawyers contend we can't take care of anybody outside that district.

Mr. Mackin: It just happens that this project is just inside the District. I think, especially in a crisis, you must take the position that you have to do the job.

Mr. Larson: We have a similar problem. Our Board is puzzled as to how far our obligation can extend. We assess the taxpayers for sewage facilities extended to government units. Are we justified in charging them? They asked permission to come in. Our Board rather feels that the citizens of the town are getting recompensed for taking

the load; then too, perhaps that is their contribution to the Cause. It isn't quite so much a question of the law but of the ethics. Are we being fair to our taxpayers?

MR. MACKIN: Do you presume that the government unit wants you to treat that sewage at no expense to them?

MR. LARSON: That's right. We don't know whether to charge them or not.

MR. MACKIN: In my case the government offered to pay. In fact, we are going to have to charge them in excess of the normal pay. They are satisfied as long as it is a reasonable bill.

J. C. SAGER, *Minneapolis:* I think the government units should be perfectly willing to carry the load. In the Minneapolis-St. Paul District, the outside areas pay the city a contributory share based on assessed valuations. There was a question as to which city it would go; it finally went to Minneapolis and the government pays so much to Minneapolis to treat that flow. We don't expect much of a load as it's only a question of neutralizing the wastes.

MR. RIEDESEL: We are now operating on an agreement on a per capita basis with Camp Grant, and have been for some time.

K. V. HILL, *Chicago, Illinois:* While a certain Army cantonment is under construction a nearby city is treating the sewage. I think they are charging the Army 4 cents per capita per month for it. The Federal Housing Authority is installing units within the limits of Rockford and I think the Housing Authority expects to pay for any service rendered.

MR. MACKIN: We have several tanks at the old Bugle Works that are just remaining idle. The sewage from the local defense area is to be pumped to these and let out at a required time, probably between midnight and 8 A.M. under ordinary conditions. This is the period of minimum flow and the procedure will enable us to stretch out our pumping and treatment capacity as much as possible. Probably many communities are not in a position to have such storage tanks available but it does show that we are not going to miss any tricks with equipments and makeshifts.

DR. HATFIELD: I got something out of this part of the discussion in this way: Apparently the Army will pay a continuing operational charge, although in our particular case they have absolutely been against such a thing. They want to make a blanket payment. They offer to give the District costs of pump stations and sewer lines and then to give a lump sum for the operation of the pumping stations for a two or three-year period. They don't want to figure any longer than that. They want to just give us a check and get out from under for the duration. They have been most fair with their figures and costs; I will say our conferences with them have been delightful.

DR. F. W. MOHLMAN, *Chicago, Illinois:* I would like to discuss an experience which, I think, brings up a rather general problem—disposal of war industry waste. For the past four or five months I have

been working with Mr. Hansen on industrial wastes. With reference to certain munitions works, these wastes were investigated some time ago and found to be very resistant to any of our ordinary types of sewage treatment. They are absolutely inert, show little or no B.O.D., but they have a very high color and a certain acidity. Someone thought of evaporation, incineration and throwing away of the ash.

Where such plants have been installed it was absolutely astounding to see the size, costs, complexity, and use of war materials in those plants. They would have to evaporate a half-million gallons per day. After we became acquainted with the problem we applied what we know about stream pollution in the United States. The policy followed of putting in evaporation plants, no matter what the size of the river, we do not consider justified. We found that with rather large dilutions, such as 1–5,000 1–10,000, 1–20,000, practically all evidences of the wastes would disappear except color. It is difficult to remove the color. With the high dilutions a very slight color remains, say about 20 parts per million. It has been our feeling that these large, expensive (evaporation) plants should not be built unless absolutely necessary. Therefore, we have felt that there should be a certain mild degree of leniency in our State Boards of Health as to general stream conditions where there are such dilutions, as in the Missouri River having a flow of 120,000 c.f.s. Toxicity usually occurs only at a low degree of dilution. We have tried to establish a policy that these wastes will go into the river in reasonable dilution.

That brings up the point that our streams really may suffer during the war effort. Alcohol and other supplies directly associated with the war effort cannot be produced without an increase in industrial wastes. Therefore, we must come to realize that our streams will suffer somewhat during war and we should have the same feeling as for priority—that is, not to make unduly expensive treatment necessary for industries that might cause only moderate pollution. The State Boards of Health will, I am sure, also be moved to feel, if there is no damage to water supply, that they will have to permit the slightly increased pollution.

DR. NICHOLS: At Merrimac they have a similar problem. Mackin has been speaking about it. This particular waste is highly colored and we found that the dilution very greatly reduces the pH. But from some experimenting it appears that it could be dumped into the Wisconsin River without raising the color of the river materially. The color fades out so you hardly notice it. As Dr. Mohlman says, it is up to the municipalities to take a lenient attitude toward these industries in connection with the war.

L. MILLER, *Indianapolis, Indiana:* In line with what Dr. Mohlman says, I think that we as engineers and material men and operators may be actively sabotaging the war effort by striving toward too much treatment. We can use up a great deal of steel and other things that are needed in the war effort and I just want to pass this onto you as a thought. We do it without realizing it.

War–Time Personnel Problems

I would like to introduce this topic because the Federation is planning certain activity in connection with the deferment under the Selective Service Act of essential and critically needed sewage works personnel. This function has arisen as a result of a resolution adopted at the recent meeting of the New York State Sewage Works Association, by which resolution the Federation was requested to investigate the possibility of obtaining such deferment for certain occupational classifications in which it has been found difficult to find replacements. Accordingly, we are proceeding to do what we can and I understand that the A.W.W.A. is also active at this time in a similar way. We are now engaged in drafting an outline of those personnel classifications in which real difficulty is being experienced and I would be glad to have suggestions or comments from any of you who have a particular problem of this kind.

It has been my own feeling that we should endeavor to carry on our work with a minimum of interference with the Selective Service or any other emergency agencies of the Federal government. At the same time, there have been some instances in which a real hardship was created by the drafting into military service of trained sewage works employees, and the Federation hopes to obtain a little more consideration by local draft boards in such instances.

We had all better become adjusted to the fact that this war is important enough to justify temporary curtailment of some of the things that we have been accustomed to doing. For instance, we have had a chemist who has always been able to carry on studies and investigations aside from the routine analytical work for the operation record. We now find that Uncle Sam needs chemists—ours among others, and you can imagine how difficult it has been to find a replacement. With our present chemist leaving next month, we are now engaged in training a young lady who has been educated in home economics and has had courses in chemistry and bacteriology. She is already proving capable of handling our routine laboratory work, but of course we do not intend to carry on any extra laboratory studies for the duration of the war.

If the Federation is successful in gaining deferment recognition for certain types of sewage works personnel, I think that we should all take the attitude that such deferment should not be sought merely because it might be obtained. It is intended to be applicable only where the service to the municipality might be seriously affected by loss of employees.

Chairman Hatfield: I might add that I have had four chemists in the past year and a half, and have not felt that I should try to hold them. My present chemist has just been reclassified and he will know in August whether he can stay with us for another six months or not. My set-up is such that I can hardly get along without a chemist.

C. C. Larson: Our experience at Springfield might give an idea as to the attitude of the Army. Mr. Walraven, our engineer, was called

into active service and our Board was rather concerned, not only because he was with the District, but also because he was virtually the only engineer left in Springfield at the time. In response to the Board's plea that he be permitted to remain at his job, the Army replied. "We realize the necessity of your having an engineer, but we also realize that our necessity is greater, and even if it means shutting down your plant we must still take him. Twenty years ago you didn't have a sewage plant and maybe you will have to go back to that situation."

L. H. Enslow, *New York City:* I am glad to hear the general opinion that the young men ought not be held back from Army and Navy service; however, I suggest that you think very carefully of what you are doing when you try to get along without a chemist or cut out some of your laboratory work, because you may have a little difficulty in selling your councils or boards on the necessity of resuming the complete program after they have seen how nicely you got along during the war.

Plant Protection

Chairman Hatfield: How many of you have made an investigation of your personnel to make certain that all of your employees are trustworthy and loyal to this nation? If you have, what type of questionnaire did you use and where did you obtain it? Perhaps there is a formal type of questionnaire that can be gotten from some organization of the government.

George Martin: The forms we use were obtained from the Wisconsin State Board of Health and I think they came originally from the A.W.W.A. The form is very complete and delves back into one's history as far back as the other war. I submitted a set of these forms to each of my men and required them to fill them out and return them for filing. If any of my men objected to using the questionnaire, I believe it would be sufficient justification for investigating him further, but I have found that they all consider it patriotic to answer the questions as completely as they can. The forms we have used are very good, in my opinion.

Chairman Hatfield: I think most of us have been negligent in considering what would happen to a sewage treatment plant if it were damaged by bombing or sabotage. I believe it is taking the wrong attitude to take for granted the fact that the sewage would simply run into the river, and that we should give more thought to the protection of the plant. Have any of you taken specific precautions?

C. C. Larson: Four months ago we instituted a system of time clocks for more positive patrolling of our property and now have watchmen making rounds at 8 stations every hour. We never felt this to be essential heretofore, but everyone in Springfield was getting fence-minded, light-minded and watchman-minded so we went that far.

R. W. Frazier: We were fortunate in already having a 6-ft. wire fence around our plant and this fence has only one main gate. We also installed a police alarm system by which the night operator reports

to the police station every hour. If there is no report, the police phone out to check with him and if they are unable to contact him a squad is sent out to investigate. If anything or anyone suspicious is observed, the man on duty merely pushes the button on the police alarm system twice, and without any further instructions a squad car comes out to check the situation.

J. C. SAGER: We formerly had 2,000 to 3,000 visitors yearly, but in December we adopted the policy of not permitting any visitors on the plant property unless they have a permit issued by the chief engineer. All buildings are now kept locked and only a few of the employees carry keys. In our plant, of course, personnel can go from one building to another by means of tunnels.

We also have arranged for the police to come down, similar to Mr. Frazier's arrangement, and we have barricaded all drives so that visitors cannot drive about the property unless admitted by permit. Our plant is well supplied with floodlights and we keep more of them in use than we did formerly.

W. H. CROPSEY, *South St. Paul, Minnesota:* We have a night man who makes the rounds every hour and followed this practice even before the emergency. All buildings are kept locked and a police cruiser visits the plant every hour through the night.

W. H. CAREY, JR.: There is one thing in connection with plant protection that has come to my attention. I would like to call it to this group's attention. Many water and sewerage plants in communities adjacent to a university are used for testing purposes. Some of the boards have misinterpreted this request that they keep visitors out of their plants to the exclusion of university students. If that is occurring in your community, you should get it straightened out at once because there is no thought that the university student with a legitimate excuse should be prohibited.

D. E. BLOODGOOD: On the night of December 7, the police chief of Indianapolis insisted that we close the three driveways entering the plant grounds, which cover 240 acres, not fenced. He insisted further that we place a total guard of eight men around the grounds with two motorcycle police patrolling the grounds. They worked on 12-hour shifts, keeping practically everybody out, and I stationed one of my employees at the gate to identify our men.

I felt that this was rather expensive as well as inadequate protection, so I presumed to suggest that the guard might be reduced. We now have one of my men at the main gate to identify employees, and a policeman on guard in one other entrance. I have tried to imagine every way that a sewage treatment plant might be sabotaged and there are so many it seems to be almost impossible to guard it effectively.

DR. M. STARR NICHOLS: On letting down during the war period. If we relax at the present time in any phase of sewage works control, we may have a reversion to some of the disease epidemics which have occurred in the not so distant past. We know it is true that typhoid death rates have geen greatly reduced by improvements made in sani-

tation with respect to the treatment of wastes discharged to streams serving as water supplies, and we also know that a water supply taken from streams cannot be polluted excessively if we are to give it satisfactory purification. I do not like to see the attitude taken that we can dispense with sewage disposal during war time since it is probably just as important for our health as is the water supply. If a plant happens to be blown up we cannot help it if the sewage goes into the stream, but we can help it until such an emergency occurs.

Priorities

W. H. Wisely: I may be able to add something to yesterday's discussion on this topic. On May 8, at the request of our Production Board officials, I met with them in Washington to furnish them with some idea of the requirements of the sewage treatment industry in the way of maintenance, operation and repair supplies. Naturally I was also interested in obtaining some ideas from them as to the interpretation of the various orders under which we are permitted to purchase such supplies.

The statistical division was interested in the total requirements of the field as regards the cost, character of the various materials used, and quantities of each. I think you will agree that these were difficult questions to answer on short notice. It was estimated that approximately $7,200,000 is spent annually for repair, maintenance and operation supplies in sewage treatment plants, and about $3,800,000 for similar purposes on sewage collection systems. A general list of the character of materials and equipment parts which are required for these purposes was also furnished but it was impossible to give any idea of the quantities of each material, because of the lack of substantial data.

I would like to suggest at this point that you may be of great assistance to the Power Branch of the War Production Board if you can furnish any representative, annual lists of maintenance, repair and operation supplies purchased, indicating the costs and amounts of the various materials. They are interested particularly in such data from plants serving 50,000 population or more.

Now, as to the status of the sewage works field in the requirements of priority officials, I was told definitely that our facilities are intended to be kept in operation. If existing preference ratings do not prove adequate, they will be revised. At the same time, we must reconcile ourselves to the fact that we cannot obtain certain critical materials as easily as we have been accustomed to, and must establish fully our absolute need for certain items.

Since yesterday's discussion, there has been some uncertainty regarding the application of the A–2 and A–5 preference ratings to sewage works. I have my original notes with me which were taken during the conference in Washington, and I have sufficient confidence in them, even though they have not been confirmed in writing by the War Production Board, to repeat that it is the intention of Order P–46 that the A–2 pref-

erence rating may be applied to sewage treatment works, and the A–5 rating to repairs and supplies required on the sewage collection system.*

When Order P–46 was drafted, the terminology used applied best to the electric and water utilities, which are the original ones coming under the authority of the Power Branch. In this order the phrase "production facilities" was meant to apply to sewage treatment plants in the same sense that it applies to electric power plants and water purification works. Also, the term "distribution system" was meant to apply to a sewage collection system in the same sense that it referred to water mains or power transmission lines. I am not taking issue with our speaker of yesterday, but I am merely passing on to you my understanding of the interpretation of Order P–46 which was received verbally during the Washington conference. Now let us assume that you have difficulty in obtaining certain supplies or repair parts under the preference ratings which are granted under P–46. If the A–2 or A–5 rating is not adequate, you must use the special PD–1A form to file an application for a higher rating to cover the specific item involved. There are two important things to remember when filing a PD–1A application: first, is the item absolutely necessary to the functioning of your facilities; and second, would it be possible to use the item if it were made of a substitute material of less critical character. These two questions must be answered by the data and information filed with the PD–1A form and if you cover these points fully in the beginning you will minimize the delay in obtaining delivery. I have found the manufacturers to be very helpful in cases such as this. Just recently I required a chrome steel tire for the traction drive wheel of a clarifier mechanism and was advised by the company that an A–1–J rating was needed for the chrome steel tire but that they were now making a complete drive wheel made of heat treated steel which could be furnished on the A–2 rating. Perhaps the heat treated steel will not last as long as the chrome steel, but for the moment, at least, it is much more important that the amount of chrome involved be used in any Army tank or airplane than in our clarifier mechanism.

Another thing that WPB officials directed attention to is this matter of the inventory which is called for under Order P–46. In most large plants a running inventory is kept and this will be ample for any audit or inspection purposes. In smaller plants where there is less demand for large inventory stocks, there is no need for an elaborate inventory and it will be adequate to simply list your purchases of maintenance, operation and repair supplies indicating the dates purchased, amounts, from whom purchased and the costs. In my own plant we listed such purchases back to 1937. Generally, the War Production Board takes the 1940 requirements as being typical of your needs.

C. C. Larson: According to your understanding you can apply the A–2 rating in the treatment plant proper?

* Confirmed in writing by W.P.B. officials under date of July 10, 1942. Order P–46 extended on June 23, to allow use of an A–1–C preference rating for emergency repairs, under certain conditions.

W. H. WISELY: Yes. In my opinion the A–2 preference rating could be applied to such items used in the sewage treatment plant as: a replacement motor for a clarifier, rubber hose, aluminum paint, pump bearings, etc.

J. C. MACKIN: May I ask you how you would apply the A–5 rating.

W. H. WISELY: Just keep in mind that the term "distribution system" in Order P–46 means sewage collection system as far as we are concerned. The A–5 rating would be applicable to such sewer maintenance and repair items as manhole frames and covers, repair parts for sewer cleaning equipment, or hose used in flushing sewers. Also the A–5 rating may be used in connection with the purchase of items needed to protect your facilities against sabotage or military damage, but you must give complete proof that such protection is essential before the rating can be applied.

D. E. BLOODGOOD: About a month ago at a meeting of the Indiana Sewage Works Association a man from the War Production Board office in Indianapolis spoke and suggested that we try the A–5 rating first and if it wasn't adequate to use the A–2. If the A–2 wasn't enough, just squall to them and the local office would see that the order went through. It simmers down to the fact that you have to squall and the amount of noise you make will be taken as the index as to how bad you need the material. To date I don't believe that we have suffered in getting any of the materials that we had to have.

CHAIRMAN HATFIELD: I haven't even had to use an A–2 rating as yet. I keep a pseudo-inventory which is made up from my monthly bills, which I believe is all right for my purpose. If you don't keep some sort of record the investigator may think you are attempting to hide something, even though you are not.

L. H. ENSLOW: In ordering parts you really need badly, don't try to put the order through without a supplementary letter, and don't be afraid of writing too much. Operators are prone to assume that the manufacturers from whom they have been buying material are fully informed as to their needs. For example, the manufacturers must account for every pint of chlorine—where it goes and what it will be used for. If you order one more cylinder than your previous orders indicate you should be using, they need a detailed account of why you need that extra cylinder. Don't be afraid to tell your story fully and to use a PD form if the manufacturer asks you to. It is up to us to help the manufacturer to prove where these materials are going.

CURRENT PROBLEMS IN LABORATORY CONTROL

CHAIRMAN HATFIELD: Let us hear about your difficulties in getting laboratory materials, modifications in procedures, or other problems of laboratory control that you may have.

C. C. LARSON: It seems to me that we are faced with using some substitute methods because of the impossibility of getting certain reagents and chemicals, such as sodium azide. The asbestos scarcity, inciden-

tally, is not a result of the war at all, but merely that the asbestos mines have become exhausted. We are trying to reclaim asbestos by cooking it up with hydrochloric acid and it seems to work satisfactorily. Manganese is another critical material and we use manganous sulfate in the dissolved oxygen determination. Some of these shortages may require us to change our methods.

J. C. MACKIN: The Gooch crucible mats can be re-used by washing with hydrochloric acid. Leaving a little moisture in them when placed in the drying oven tends to make the asbestos soft and fluffy.

F. E. HARROUN, *Akron, Ohio:* In connection with crucible methods, I ran into a snag and started some research on it. I found a method whereby some of the poorer grades of asbestos could be used. Small discs of filter paper, very course, are placed in the bottom of the crucible, over which is poured a mixture of poor grade asbestos. The filter paper prevents small fibers from getting through the crucible. On the asbestos mat we pour a mixture of Celite filter aid, manufactured by Johns-Manville. The idea of the filter aid is to prevent solids from getting down into the asbestos mat. After a determination you can carefully scratch off the surface of the filter and use it over again, getting practicaly the same speed as in the original filtration. This mat will give you about ten to twelve uses of the filter. Filter-Cel is also very good—you'd be surprised how much faster. If you can get an old type of asbestos and use this filter aid on top of it, you have a very fine crucible. You must be careful, however, to put about ⅛-inch of asbestos in the crucible.

C. C. LARSON: Can you ignite a crucible made up with the filter paper and filter aid?

F. E. HARROUN: I believe you could. I imagine the filter paper is about the size of a nickel and that is very negligible in ash weight. We have discontinued ignition of suspended solids at Akron.

C. C. LARSON: I have used sintered glass crucibles which have porous bottoms and these will not stand igniting in a muffle furnace. They are quite expensive and I use many of them. They seem to stand up fairly well, by just washing them with cleaning solution.

D. E. BLOODGOOD: If you have trouble in getting aluminum foil for nitrate determinations you may be able to get some aluminum milk bottle caps in some cities. To conserve our supply we use smaller pieces of aluminum foil and weight them with glass beads.

C. C. LARSON: Most aluminum is quite pure. I used some wires we salvaged from wire fence and there was some question as to its purity, but it seemed to work all right.

W. D. HATFIELD: I understand that azide for dissolved oxygen determination cannot be obtained at this time. I have enough to last about a year, but we will probably change methods after our supply is gone. The sulfamic acid procedure can be used in place of azide, however it goes back to four solutions. It is cheaper and has some very definite advantages over azide, but is a more cumbersome procedure.

TIPS AND QUIPS

Under date of June 23, 1942, the War Production Board issued an important amending order to Preference Rating Order P–46 which is applicable to maintenance, repair and supplies for utilities (including sewerage services). Preference rating assignments are now as follows:

(1) *Producers*

(i) A–2 to deliveries, to a producer, of material which is required by him for the maintenance and repair of production and pumping plant facilities, and to deliveries of operating supplies for such facilities.

(ii) A–5 to deliveries, to a producer, of material required by him for the maintenance and repair of all other facilities, and to deliveries of operating supplies for such facilities.

(iii) Subject to the provisions of paragraph (e) (2), deliveries, to a producer, of material required by him for the construction of transmission, switching and distribution facilities necessary to serve new projects bearing a rating of A–5 or better, or to serve new equipment the delivery of which is rated A–5 or better, are assigned the same rating as is assigned to such new project or to the delivery of such new equipment; except that where such project or such new equipment is assigned two or more ratings and both or all of these are A–5 or better, such deliveries to a producer are assigned the lowest rating which is assigned to such new project or equipment.

(iv) Subject to the provisions of paragraph (e) (2), A–5 to deliveries, to a producer, of material required by him for protection against sabotage, air raids, or other hostile acts, provided such protection is directed by an authorized federal or state agency.

(v) On or after July 1, 1942, A–1–c to deliveries, to a producer, of material required by him for repair of an actual break-down of existing facilities, or to make reasonable advance provisions for such repair, provided that such A–1–c rating shall not be applied to more than 30 per cent of the material within any class which could be scheduled for delivery in each calendar quarterly period under the provisions of paragraph (f) of this order.

(2) *Suppliers.*—The same preference rating is assigned to deliveries, to any supplier, of material required for any of the purposes specified in paragraph (b) (1) or to be physically incorporated in such material so required by the producer, as is assigned to such deliveries by paragraph (b) (1).

Paragraph (e) (2), having to do with the application of the ratings permitted under paragraphs (iii) and (iv) above, is amended to read as follows:

In addition to the requirements of paragraph (e) (1), a producer, in order to apply the preference rating assigned by paragraphs (b) (1) (iii), and (b) (1) (iv), or in order to withdraw material from stores or inventory for the purposes spesified in said paragraphs, must, unless otherwise directed, communicate with the Power Branch, War Production Board, Washington, D. C., Ref: P–46, supplying in detail the following information or such other information as may from time to time be required.

(i) Description of the project to be built by the producer, including a print of proposed line construction, showing size of wire, or pipe, capacity of transformers, and other information relevant thereto.

(ii) Relation to military needs, war production, public health or safety.

(iii) Copy of customer's preference rating certificate or order, and, in case of materials rated under paragraph (b) (1) (iv), copy of order of federal or state agency.

(iv) Whether service can be rendered in any other way, or by any other producer, with use of smaller quantities of critical materials.
(v) Cost of materials.
(vi) Total cost of producer's project.
(vii) List of materials required for the construction, including the weight of copper or steel required.

The Director of Industry Operations will notify the producer whether and to what extent the application is approved. A copy of such notification shall be furnished by the producer to any supplier to evidence the proper rating granted pursuant to the provision of this order.

* * *

Upon inquiry, the Federation's Secretarial office has been informed that the W.P.B. is compiling a mailing list of municipal sewerage services for the purpose of furnishing important priority orders as they are issued. It is suggested that anyone interested, write to the War Production Board, Power Branch, P–46 Section, Washington, D. C., to make certain that the list includes your name and address.

* * *

Illinois' voluntary certification program for sewage works operators continues to make progress as shown by the participation of operation personnel during 1941. The numbers of certificates issued in the various classes are tabulated below:

Grade	New	Inactive	Total in Force
Class I	2	1	7
Class II	12	5	30
Class III	22	14	38
Class IV	1	—	1
Totals	37	20	76

Several important changes were adopted in the classification requirements: graduate work in college or university will be acceptable as equivalent for operation experience to a maximum extent of one year in responsible charge or two years of subordinate experience; the Class III requirements are now two years of high school education, three years of operation experience and a service rating score of 40 or more in the required examination; a new Class IV has been added requiring a grammar school education and one year of operation experience. Operators in states other than Illinois are also now eligible to apply for Illinois certificates, providing that the classification granted is approved by the state agency that has jurisdiction over sewage works operation in the state of residence of the applicant.

The Illinois plan has no legal foundation but enables sewage works operators to establish their respective qualifications by voluntary participation. It is certainly a move in the right direction and may some day be the stepping stone to a state registration law.

President Kerwin L. Mick of the Central States Sewage Works Association is ordinarily distinguished by his dignified, reserved and studious mien. The cause of his transformation into the exuberant toothpaste advertisement in the photograph appearing in these pages was the occasion of the presentation of the Federation's Convention Attendance Award to the Central States Association during the June 18–19 meeting of the latter organization at Minneapolis.

The winner of the award is determined by aggregating the miles travelled by individual members of the Federation's Member Associations in attending the Annual Meeting. In attendance at New York last year, 49 Central States members travelled a total of 38,600 man-miles to lead the host New York State Association, with 185 members present, by 10,000 man-miles. The custodian of the trophy for 1942–1943 will be determined at Cleveland on October 22–24.

Kerwin L. Mick, Chemist of the Minneapolis-St. Paul Sanitary District and current President of the Central States Sewage Works Association

Where does it go from here?

* * *

The Waterloo, Iowa sewage treatment plant is producing digester gas in "powerful" fashion, according to Superintendent C. T. Wilson. During the period January 1, 1941 to April 1, 1942 a total revenue of

$23,841 was derived from the sale of excess gas to the local gas and electric utility.

Paging Mr. Insull!

* * *

One of our leading weekly picture magazines is already relegating the versatile Army Jeep to the junk heap at the end of the war. It would seem that a few of them might find homes in sewage treatment plants, where their light weight, power, ruggedness and compactness

Who will win it in October?

would make them useful in a number of ways. Equipped with a dump bed, they might be used for cleaning sludge beds in the same way as are tractors in some midwestern plants, or they might be used for light sewer patrol and maintenance, for pulling grass mowers, road-shaping devices and snow-plows.

We should be able to find some ways to use those machines in the preservation of human lives as well as in the destruction of them!

* * *

C. C. Larson of Springfield, Illinois defied convention recently in an effort to recondition some of the sludge drying beds which had become compacted. The ordinary hand raking performed after the beds

were cleaned seemed to be only superficial in effect and the sand seemed to be badly caked beneath the surface.

A farmer's disc plow was pulled over the beds by a small tractor and the media of the beds was thoroughly scarified to a depth of four inches. Reports Larson, "We, of course, penetrated into the gravel layers and this may have been unwise but we certainly did pulverize the filtering surface."

* * *

Tired of changes
In the map?
Then BUY WAR BONDS
And slap the Jap!

AND BE AT CLEVELAND ON OCTOBER 22–24
FOR THE
CONFERENCE ON WARTIME SANITATION!

Editorial

AIMS OF THE FEDERATION

The Federation is well on its way toward achieving the objectives that were set forth in its reorganization last year. For years it has been realized that more personal service for the plant operator was needed, but the limited budget prevented much expansion of operators' articles in the JOURNAL, and practically no service committees nor personal visits of officers to meetings of local associations were possible. Years of effort to obtain more articles on plant operation by and for operators of sewage treatment plants resulted in some increase in this section of the JOURNAL, but it was found that such articles are rarely contributed voluntarily, and must be evoked by personal correspondence or actually by visits of some editorial representative who could suggest what features of plant operation should be described, and how the article should be presented for publication.

No such personal service was possible and therefore this important phase of the JOURNAL's service was limited to whatever could be brought in by operators' sessions at meetings of local associations, gadget contests, reviews of annual reports and some contributed articles.

The only way by which it seemed possible to reorganize and expand this function was by the appointment of a secretary who knew and appreciated the problems and needs of the plant operator. The country was scoured for this man and he was found. "Pete" Wisely was suited so perfectly for this position that it seems as if Providence groomed him for his new duties. He had been a widely known member of the Illinois State Sanitary Engineer's staff and at the same time Secretary of the Central States Sewage Works Association. In this dual capacity he brought the Central States Association up to its maximum membership and became widely known among the operators of the central states. He was more widely known as editor of *The Digester,* the sewage works news organ of the Illinois State Department of Health. His ability to find the interesting facts of plant operation, and his pleasing personal style of writing about the operator "day-by-day," made *The Digester* well known from coast to coast.

Later, as operator-manager of the Urbana-Champaign Sanitary District he lives the operator's life from day to day and knows their problems and their rewards of service.

This near eulogy of Pete Wisely extends the Editor's enthusiasm beyond its usual reserve, but we feel his services should be appreciated as much by all the members of the Federation as they are by the Editor.

Besides this service in the JOURNAL, Mr. Wisely is visiting as many local meetings as possible, taking care of the business affairs of the Federation, and aiding the operators and superintendents by a per-

sonal study of priorities and conservation of technically trained men in civilian operation of sewage treatment works.

Other aims of the Federation are being met by work of committees, as reported by Morris Cohn in this issue, and by George Schroepfer at the last annual meeting. Dr. Rudolfs continues the important service of issuing the annual report of the Research Committee. Arthur Bedell has devoted much of his time to executive affairs of the Federation, and conservation of personnel in the sewage works field during the war.

The mention of research calls up a brief discussion of the research phase of the Federation's activities. The JOURNAL has long held the position of the best research journal in the field of sewage treatment, stream pollution and industrial waste disposal, as may be proved by consideration of the predominance of references to the JOURNAL's articles in all bibliographies or references to sewage literature. The research function of the JOURNAL continues to advance and the excellence of our research articles has improved with the passing years. It is the Editor's function and policy to improve and expand the research articles in the JOURNAL. Our improving financial status should make it possible to do this, in addition to the expansion of operators' articles. We believe all far-sighted members of the Federation do not want to see any limitation of research articles in the JOURNAL by reason of undue emphasis on practical articles on plant operation or other important phases of the Federation's activities.

The manufacturers are our esteemed friends, for their advertising fees go far to support many of our non-commercial activities. Therefore, we are glad to donate annually the space for their contributions, which have been prepared carefully to present impersonal scientific discussion of new developments in their products. We believe their contributions make very interesting reading, and most of them are quite reserved, in view of the advertiser's proclivity to blow his own horn.

Thus we are striving to meet the three main needs of the Federation: (1) to improve the service to the plant operator; (2) to maintain the scope and standards of research articles in the JOURNAL; and (3) to cooperate with the manufacturers and advertisers in presenting their contributions to advancement of the science of sewage disposal.

Committee reports and personal service of the Federation may be of value in promoting any of these three activities. The main fact is to recognize that a comprehensive plan is now under way to improve the scope, service and standing of the Federation as the organized representative of the field of sewage disposal in the United States.

F. W. M.

Proceedings of Local Associations

CALIFORNIA SEWAGE WORKS ASSOCIATION

Fourteenth Annual Spring Convention

Bakersfield, California, April 26–28, 1942

Sunday, April 26

Operators' Symposium.—President Fred D. Bowlus called the Conference to order at 8:00 P.M. in the Tower Room of the Motel Inn with 46 members present. Serious discussion was soon under way on the many experiences and problems of sewage plant operation and maintenance. Gas engine operation and cost of maintenance, sludge heating and digestion, sprinkling filters, sewer main cleaning, grease problems and control at army camps, and insect control were thoroughly discussed with almost every one having something to say. Plans and specifications for screen chambers and requirements for connections of dairies to sanitary sewers as recently adopted by the Los Angeles County Engineers Office were offered to the Association for its consideration by Arthur Pickett of that office. After considerable discussion Mr. Reinke suggested that this subject of dairy waste control would make a good paper for the next meeting. No action was taken at the time.

Monday, April 27

Business Meeting and Papers.—With 56 members present, President Bowlus opened the meeting at 9:30 A.M. by introducing Mayor Alfred E. Siemon, of Bakersfield, who welcomed the members to his City and expressed their pride in Bakersfield's modern disposal plant.

Progress reports from the chairmen of the various committees were called for. Mr. Pickett of the Membership Committee reported that there were a total of 219 active members, 25 of whom had preferred the $2.50 dues whereby only alternate issues of the Sewage Works Journal are received. Plans for a membership drive are just under way. F. Wayland Jones of the Publicity Committee stated that announcements of this convention had been carried in the local paper and that the scrap book of Association activities was up to date and ready for display. President Bowlus, reporting for the Committee to Finance the *California Sewage Works Journal,* stated that the cost of our last Journal, Volume XIV, No 1, was $356.17 and the total income from advertising was $332.50, making a deficit of only $23.67. It is expected that this deficit will be made up when the next issue is printed. Mr. Hoskinson, chairman of the Legislative Committee, reported that there had not been any sewer legislation at the special session of the State Legisla-

ture. He reviewed the recent work by the State Civilian Defense Orgnization and explained the functions of the Committee on Water Supply. The Secretary then reviewed the progress report mailed in by Chairman Kenneth W. Brown, of the Joint Committee on certification of, and schools for, sewage plant operators. Mr. Brown's committee has already contacted 65 sewage treatment plants, and 60 water plants, with a form letter giving complete information concerning certification requirements, and with a brief questionnaire requesting information as to the number of operators who would care to take a correspondence course and the type of treatment process in which they would be particularly interested. It is the plan of this committee to send the information to the operator by mail and to increase the number of places where eligible operators may take an examination for a certificate. This program is ready to go as soon as they find out how many operators wish to participate. The Secretary also read the following report mailed in by Leon B. Reynolds of the Constitution Committee:

Two matters have been referred to this committee by Secretary Kimball with the approval of President Bowlus, as follows:

1. The Division of Public Health Engineering and Sanitation of the Utah Department of Health requested a cooperate membership. Under our Constitution only one kind of membership is provided for and it specifically states that "any person, or any Board, Commission or Department interested . . . may be a member." Under this provision we already had one Department as a member and our committee was unanimous in ruling that the Utah Department could be a member and entitled to one vote.

2. Our By-Laws provide that we shall publish a Journal with all papers as our property subject to publication in the Journal of the Federation without impairment of the right of the Association to publish them in the California Journal. This provision is in conflict with one of the rules regarding publications of Member Associations adopted by the Board of Control of the Federation. Our committee is unanimous in its desire to adhere to the provisions of our By-Laws.

Respectfully submitted,

LEON B. REYNOLDS, *Chairman,*
C. C. KENNEDY,
A. M. RAWN.

A progress report of the Industrial Wastes Committee prepared by Chairman W. T. Knowlton was read by H. K. Palmer. Information on the types and quantities of industrial waste have been received from twenty-one cities. This data will be reported at the Fall meeting.

President Bowlus then introduced W. H. Wisely, Secretary of the Federation of Sewage Works Associations, who had flown to California from Illinois especially to attend our Conference and to give us a clear picture of the aims and activities of the Federation. Mr. Wisely assured the members that the Federation was making progress despite the present war conditions and that most of the problems incident to the reorganization in 1941 have been solved. Even with only part-time supervision and limited office help every effort has been made to handle Journal subscriptions promptly and to restore the Journal to its intended publication schedule. Mr. Wisely stated that he is trying to

develop the plant operation section and that past contributions by the members of the California Association have been appreciated and he hopes that this fine cooperation will continue. The membership at the present time has passed the 2,000 mark as compared to 2,896 in 1941. Only 39 members have chosen alternate subscriptions to the Journal. Very good progress has been made by the committees along the line of present-day problems and their reports will be of interest to all. The Third Annual Convention will be held at Cleveland on October 22–24, 1942 with a program devoted to war-time problems.

The first paper, "Treatment of Cannery Wastes," was presented by Earl M. Kelly, Sanitary Engineer for The Dorr Co., Inc. A discussion on industrial wastes disposal and its effect on sewage disposal in small cities followed Mr. Kelly's paper with the following men presenting their particular problems: E. P. Hapgood, City Engineer of Anaheim; G. L. Walters, Water and Sewer Superintendent of Fullerton; Harold L. May, Asst. Water and Sewer Superintendent of Palo Alto; and A J. Castro, Superintendent of the Santa Clara Sewage Treatment Plant.

At 11:00 A.M. President Bowlus asked Ed. A. Reinke, Senior Sanitary Engineer, State Department of Public Health, to lead a discussion on "Bomb Disaster Plans" and stated that all statements would be confidential and would not be recorded.

Caravan.—The caravan formed immediately after the meeting and proceeded to Minter Field where an excellent lunch was served to fifty of the members at the cadet's mess. Immediately after lunch the members were treated to a tour around the Camp and then inspected the sewage treatment plant. The Caravan proceeded to Shafter and then to Wasco where each sewage plant was visited. The Bakersfield plant was the last stop and considerable time was spent there to look over the many recent developments in design and in mechanical equipment. Eugene Ceriat presented a demonstration on the clarification of sewage using chemicals and a model sized plant.

Annual Banquet.—An exceptionally good banquet was enjoyed by eighty-two members and guests in the Fiesta Room of the Motel Inn. After dinner the group was entertained by a men's trumpet trio and by a women's vocal trio presented by the Music Department of the Bakersfield High School. Before presenting the guest speaker, President Bowlus made a few remarks and expressed his appreciation of the splendid attendance. He then introduced the various guests of honor; W. H. Wisely, Secretary of the Federation; Mr. Stunkard, Sanitary Engineer for the U. S. Engineers office at Salt Lake City; Mrs. Carl Hoskinson; First Vice-President Carl Hoskinson; Second Vice-President Richard Pomeroy; William A. Allen, Representative to the Federation Board of Control; Mrs. Frederic Batty; and the past presidents Frederic Batty, Edgar A. Reinke, and Harold F. Gray. President Bowlus then introduced the guest speaker of the evening, Lewis H. Kessler, Chief for the Sanitary, Engineering, Water, Sewer and Service Unit, Repairs and Utilities Branch, Construction Division, Office Chief of Engineers. Mr. Kessler's address, "Sewage Treatment at Army

Posts," was a comprehensive review of the problems and results in the design, maintenance and operation of sewage treatment plants constructed by the War Department under the Selective Service Act of 1940. Mr. Kessler's paper was so very interesting that he was kept busy for several hours after the banquet answering questions and discussing the subject with many of the members, several of whom were connected with Army camps in California.

TUESDAY, APRIL 28

Papers.—With 44 members present President Bowlus called on Uno H. Errikson, Superintendent of the Bakersfield sewage treatment plant for a brief review of his operating problems and results. T. V. Little, Engineer for the Shafter sewage plant, described his plant and the various current operating problems. As Eugene Ceriat was present, he was asked to explain the principle of his model sewage clarification unit demonstrated the day before at the Bakersfield plant.

The first paper of the morning, "Sewage Works Industry in War Time," was presented by W. H. Wisely, Secretary of the Federation of Sewage Works Associations. Lieutenant Herbert B. Foster, Sanitary Corps, Camp Callan presented a paper on the operation of the Camp Callan sewage treatment plant. "Research on Sulfide Control" by Richard Pomeroy, Consulting Engineer-Chemist, was the last paper on the program.

President Bowlus adjourned the conference at 12 o'clock noon.

Jack H. Kimball, *Secretary*

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Thirteenth Annual Meeting

Boston, Massachusetts, May 27–28, 1942

The thirteenth annual meeting of the New England Sewage Works Association was held on May 27–28, 1942, at the Hotel Bradford in Boston, Massachusetts. Seventy-eight members and guests were registered for the meeting. This was the lowest attendance since the annual meeting on October 15, 1930, at the Hotel Raymond in Fitchburg, Mass., when there was an attendance of only 45. However, much favorable comment was made relative to the Fitchburg meeting as was also to the current meeting so that perhaps low attendances accompany good meetings. The present low attendance is attributed to the shortage of tires and gasoline, and the war activities of many of our members.

At 10:15 A.M. the business meeting was called to order by President Samuel M. Ellsworth. The Secretary read his reports which were accepted. The following 1943 officers were elected:

President: Roscoe H. Suttie of New Haven
First Vice-President: Joseph A. Muldoon of Bridgeport

Second Vice-President: Frank L. Flood of Boston
Secretary-Treasurer: LeRoy W. Van Kleeck of Hartford
Director: Eskil C. Johnson of Providence
Director: Robert Burrell of West Haven
Director: Thomas R. Camp of Cambridge

The first speaker on Wednesday morning was Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn., who presented a paper on "Classification of Inland and Shore Waters in New England." Arthur D. Weston, Chief Engineer of the Massachusetts Department of Public Health, Boston, Mass., prepared a written discussion which was presented by Edward Wright of his office.

The second paper of the morning on "The Application of Laboratory Results to the Operation of Sewage Treatment Processes" was presented by F. Wellington Gilcreas, Associate Sanitary Chemist, Division of Laboratories and Research, New York State Department of Health, Albany, New York. Mr. Gilcreas' paper was followed by considerable general discussion from the floor.

In the absence of Frank Flood, Chairman of the Association's committee on the status of operators' salaries in New England, Willis J. Snow, a member of the committee, presented a progress report. Discussion of the subject was opened by A. F. Dappert, principal sanitary engineer, New York State Department of Health, Albany, N. Y. It was the concensus of the members present that the committee should present its final report at the earliest possible moment. Present as the Association's guests at the luncheon were Commissioner Hyland, of the Boston Public Works Department, Division Engineer, Robert P. Shea of the Boston Department of Public Works, and Arthur S. Bedell, President of the Federation of Sewage Works Associations. The Honorable Maurice J. Tobin, Mayor of Boston, addressed the Association following the luncheon.

Following Mayor Tobin, Mr. Bedell talked to the Association members on the activities of the Federation. He extended a cordial invitation to attend the third annual convention of the Federation in Cleveland, Ohio, this fall.

A brief address was also given by Major J. H. Brewster of the United States Public Health Service on the necessity of prompt repairs to sewers following sabotage or aerial bombardment. Close cooperation between sewer and water supply repair squads is needed, he stressed, if water is to be supplied to vital water industries.

Following these speeches, Robert P. Shea, division engineer, Department of Public Works, Sewer Division, Boston, Mass., presented a paper on "Sewer Maintenance." His talk was followed by a visit to the Boston sewer maintenance department on Western Avenue, Brighton, Mass. The trip was made by autos furnished by the Boston Maintenance Department and by taxis. A well-planned program was arranged by the Boston Department for the inspection trip. First was a display of

sewer cleaning apparatus and other equipment at the yard. This was followed by a demonstration of cleaning sand from a sewer by the use of a rubber cup and water pressure. The use of flexible rods was also demonstrated. A sewer and two manholes were constructed especially for the inspection with a section of the sewer made of glass so that the action of the water and cup could be observed by the members. The method employed in freeing a stopped sewer in a street near the maintenance yard was also demonstrated with the use of cleaning equipment. A catch basin cleaning machine was also operated for the members. Through the cooperation of William A. Reilly, Fire Commissioner of the City of Boston, Lt. F. W. Kelly, of the Fire Prevention Division, staged a demonstration on the handling of incendiary bombs.

In the evening the Association held its annual banquet in the roof ballroom of the Hotel Bradford, and listened to an address by Professor Samuel C. Prescott, Dean of Science and Head of the Department of Biology of the Massachusetts Institute of Technology. Professor Prescott spoke on dehydrated foods. His talk was very favorably received.

On Thursday, May 28, 1942, following the Association breakfast, there was a general discussion of war-time preparation for sewer repairs and treatment plant protection. Opening remarks were made by Warren J. Scott of the Connecticut State Health Department. Then followed a series of subjects on plant operation. The first of these was given by Nicholas DeHass, superintendent of the sewage treatment plant at Linwood, Mass., on the operation of sand filters. The second topic was on the operation of trickling filters opened by Roy S. Lanphear, superintendent, sewage treatment plant, Worcester, Mass. The third subject was opened by Paul C. Martzell, Superintendent, Grass Island sewage treatment plant, Greenwich, Conn., on the handling of grit. The next subject on raw sludge pumping was opened by Walter A. McMahon, superintendent, sewage treatment plant, Torrington, Conn. The last subject on handling scum accumulations in separate sludge digestion tanks was opened by Paul V. Fleming, superintendent, sewage treatment plant, North Adams, Mass.

Following the noon day luncheon, members of the Association inspected the sanitary engineering laboratories at the Harvard Graduate School of Engineering in Cambridge, Mass. Thus ended the thirteenth annual convention.

LeRoy W. Van Kleeck, *Secretary*

Federation Affairs

EQUIPMENT SHOW AND PRIORITIES CLINIC WILL FEATURE SEWAGE WAR CONFERENCE

J. V. N. Dorr, Luncheon Speaker

Preparations for the **Wartime Conference on Sanitation,** to be staged by the Federation of Sewage Works Associations at the Hotel Statler, Cleveland, Ohio, October 22–24, are nearing completion by the Convention Management Committee and the local arrangements groups. This meeting will be a "must" for the sewage works profession at a time when equipment shortages, materials priorities and wartime operation problems are imposing new operating conditions on thousands of sewage and waste treatment works in the United States. The third annual meeting of the Federation is specifically aimed at the solution of these emergency problems.

The Exhibits Committee, under the chairmanship of Arthur T. Clark, has announced that the convention will feature an equipment show which will have unusual significance in war times. Leading manufacturers of equipment and supplies will exhibit their products and give advice to municipal authorities on the care and conservation of existing equipment and materials stocks.

The Federation will conduct a "Priorities Clinic" at which W. H. Wisely, Secretary, L. E. Rein and leading authorities will give advice and guidance to those municipalities faced with immediate materials and equipment needs. The constant change in priorities regulations should result in active participation in this timely clinic.

The entire convention program, prepared under the guidance of F. W. Gilcreas, will have a wartime character. A. M. Rawn and H. G. Baity will discuss the impact of war on sewage treatment problems. L. H. Kessler and Guy Griffin will present data on the operation of sewage treatment plants in military cantonments. L. F. Warrick will analyze wartime sanitary problems of a state health department. W. A. Stinchcomb will discuss local civilian defense problems.

Operators will engage in a symposium on plant maintenance in war time, led by C. C. Larson. The technical sessions will feature war problems.

The sewage treatment system of the City of Cleveland will be inspected by the Convention. Entertainment for members and guests is being planned, commensurate with wartime transportation and other restrictions. W. L. Havens, Chairman of the Convention Management Committee, has announced that the Convention will be a fitting sequel to the Chicago and New York meetings. The Committee has announced that J. V. N. Dorr, President of the Dorr Company and eminent scientist, will be the featured luncheon speaker.

The Federation will meet in Cleveland under the joint sponsorship of the Ohio Conference on Sewage Treatment, and all committees have representatives of both the Federation and the Conference. Those in attendance from other state associations will have the opportunity for state reunions and will compete for the reunion cup awarded to the group traveling the greatest man-miles. The veteran operators of the Quarter Century Club will again be honored at the meeting.

The meeting is ideally timed to meet the restrictions on travel. One trip will permit members to attend the meeting of the Federation, and to participate in the sessions of the American Public Works Association, to be held in the same hotel during the four days prior to the Sewage Works Conference, and then to travel to St. Louis for the American Public Health Association meeting.

The Convention Committee has adopted the slogan . . . "Cleveland in October . . . It's a Must!"

MORRIS M. COHN, *Chairman,*
Publicity and Attendance Committee

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

TENTATIVE PROGRAM

WARTIME CONFERENCE ON SANITATION

(Third Annual Convention)

October 22, 23, and 24, 1942

Cleveland, Ohio
Hotel Statler

Wednesday, October 21

7:00– 9:00 P.M.	Registration
7:00– 9:00 P.M.	Inspection of manufacturers' exhibits
8:00–10:00 P.M.	Pre-convention get-together

Thursday, October 22

8:30 A.M.	Registration
9:00 A.M.	Inspection of manufacturers' exhibits

TECHNICAL SESSION

Presiding—A. S. BEDELL

10:00 A.M.	Third Annual Convention—Federation of Sewage Works Associations — A. S. BEDELL
	Greetings from Cleveland — HON. FRANK J. LAUSCHE, MAYOR
10:30 A.M.	"The influence of the national emergency on sewage treatment problems" — A. M. RAWN
11:30 A.M.	Adjournment
12:00 NOON	Luncheon and Business Meeting of Ohio Conference on Sewage Treatment

TECHNICAL SESSION

Presiding—G. J. SCHROEPFER

2:00 P.M.	"Sewage purification by flotation" — C. A. HANSEN AND H. B. GOTAAS

2:45 P.M.	"The need for short training schools in sewage treatment during the present war emergency"	H. E. Babbitt
	Discusser:	A. H. Hall
3:30 P.M.	"Operation of sewage treatment plants in military cantonments"	L. H. Kessler and John T. Norgaard
	Discusser:	G. E. Griffin
4:15 P.M.	"Wartime sanitary problems of a state department of health"	W. F. Shephard
5:00 P.M.	Adjournment	
8:30 P.M.	Smoker	

Friday, October 23

TECHNICAL SESSION

Presiding—A. S. Bedell

9:00 A.M.	"Sewage treatment problems in Cleveland"	J. W. Ellms
	Discussers:	W. Donaldson
		J. J. Wirts
9:45 A.M.	"Pre-treatment of chemical wastes"	W. Rudolfs
	Discusser:	E. T. Killam
10:30 A.M.	"Sewage works priorities"	W. H. Wisely
	Discusser:	L. E. Rein
11:15 A.M.	"Local civilian defense problems"	W. A. Stinchcomb
12:00 NOON	Adjournment	
12:30 P.M.	**Federation Luncheon Guest Speaker:**	**J. V. N. Dorr**

TECHNICAL SESSION

Presiding—A. H. Niles

2:00 P.M.	Symposium—"Sewage plant maintenance in war time" Leader:	C. C. Larson
	A. Mechanical units	J. W. Johnson
	B. Electrical equipment and power sources	H. V. Crawford
	C. Grounds—including visitors and protection	A. B. Cameron
	D. Maintenance of sewers	R. L. Phillips
5:30 P.M.	Adjournment	
7:30 P.M.	Dinner and dance	

Saturday, October 24

8:30 A.M.	Breakfast

OPERATORS' TURN-TABLE

9:30 A.M. "Significance and value of laboratory tests in sewage plant operation" Leader: L. W. VAN KLEECK
A. Sampling and preservation of samples
B. Biochemical oxygen demand and dissolved oxygen
C. Settleable solids and suspended solids
D. Relative stability
E. Grease
F. Other tests

11:00 A.M. Business meeting—Federation of Sewage Works Associations
A. S. BEDELL, Presiding

12:00 NOON Inspection trip—Cleveland Sewage Treatment Plants

12:30 P.M. Buffet luncheon—Cleveland Sewage Treatment Plant

5:30 P.M. Dinner meeting—Board of Control

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

PROGRESS REPORT OF THE SEWAGE WORKS PRACTICE COMMITTEE

(An informal statement by MORRIS M. COHN, *Chairman*)

General. The Sewage Works Practice Committee is charged by the Constitution with the task of serving in a judicial capacity on reports, publications, resolutions and professional and technical standards which are issued in the name of the Federation. Regardless of what additional functions the Committee assumes, this judicial capacity must be considered its paramount responsibility. One such judicial task was performed by the Committee since October, 1941.

It is the consensus of the Committee that it should undertake the planning work on a Manual of Practice in the sewerage and sewage treatment field and should either guide the development of the Manual by sub-committees or judicially review it for publication, with the Publication Committee, when the book is completed. The Committee has undertaken preliminary work in this connection.

A number of national engineering and scientific societies are now performing work in the field served by the Federation, through various technical committees of these societies. It is essential that the Federation take its rightful place in national sewerage and sewage treatment committee work, and to be recognized as the specialized professional voice of this specialized field. Before the Federation can achieve this position it must know what other societies are doing and offer to perform jointly some of the committee functions now being performed by existing groups. Further, it must strive to evaluate the work now being done and to plan to fill the gap between present programs and what should be done to assure full and adequate knowledge of all aspects of sewerage and treatment design, construction, operation, control and maintenance. By such coordination of committee efforts valuable time can be saved, and the studies undertaken will have the benefit of the greatest possible experienced personnel.

The Sewage Works Practice Committee has undertaken to perform this important coordination work, in its initial stages, and to bring the program to a point where the proper Federation Committees can take over specific relations with the other national sewage committees. Some work was performed by the Committee since October, 1941, in keeping with this policy.

The above comments, in the main, outline the aims of the Committee, to date, and indicate whether any activity has been started in the three fields of committee endeavor which have occupied its attention since October, 1941.

Judicial Action. The Committee received its first assignment in the field of approving standards of practice for the Federation, when the American Society for Testing Materials presented its Tentative Specifications for Vitrified Clay Filter Block for Trickling Filters, C159–41T, to the Federation for advice and approval.

The Committee was circularized for its comments and criticisms of the tentative standards and their findings were transmitted to the Executive Secretary for presentation to ASTM. This is the first evidence of the desire of national groups to obtain the reactions of the Federation in matters pertaining to our professional field.

Proposed Manual of Practice. The members of the Committee were canvassed to obtain their recommendations on the proposed Manual of Practice. Reactions ranged from suggestions that any such work be postponed for the duration, to opinion that such a manual be prepared for the full scope of sewerage and sewage treatment, in textbook coverage manner. Between these divergent opinions were suggestions that the Federation sponsor a manual on operation methods, only; that a series of manuals be planned, each devoted to one specific problem, such as design, materials of construction and operation, etc.; that an exposition of the recognized practices be prepared slowly over an extended period of time.

The Committee will attempt to sift down these suggestions into some definite plan of action, in time for the Annual Meeting, at which time the Federation can plan the preparation of parts of the Manual program.

Coordination of Technical Activities. The Committee has undertaken the task of: (1) surveying the various sewerage and sewage treatment committees now functioning in the country; (2) obtaining the reactions of the various societies to joint action with the Federation in these studies; (3) planning such studies as will fill the gap between the work now underway and that which should be carried out.

On May 20, the Committee addressed the following letter to the following organizations: Conference of State San. Engrs.; Conference of Municipal Public Health Engrs.; A.P.H.A.; A.W.W.A.; A.S.C.E.; A.P.W.A.; A.S.T.M.; Amer. Chemical Soc.; Amer. Instit. of Chem. Engrs.; Tech. Assoc. of Pulp and Paper Industry.

Dear Sir:

The recently reorganized Federation of Sewage Works Associations has appointed a group of national committees to carry on research and investigation work in the field of sewerage and sewage treatment, which is represented by this specialized professional organization. The Sewage Works Practice Committee will establish standards of practice and serve in a judicial capacity on matters which become the established standards of the Federation.

Now, of all times, it is essential that there be no duplication of effort among the various professional groups and, further, that any investigation being con-

ducted shall have the unselfish benefit of all groups vitally affected by the studies underway.

For this reason, the Federation of Sewage Works Associations is addressing various organizations in the country, whose committees may have been investigating various direct or indirect aspects of sewerage, sewage treatment, waste disposal and stream pollution. The Sewage Works Practice Committee is assuming three functions in this connection,— (1) the conduct of a survey showing the various studies now underway; (2) the offer of cooperative effort by Federation Committees with committees from other organizations now functioning in the significant fields; (3) the planning of studies which might fill in the gap between the work now being conducted and the search for a fuller fund of knowledge on these subjects.

To the end that we might intelligently plan our work, can you supply us with the following information: (1) the names and personnel of committees now carrying out work of the above enumerated nature, and (2) indication of whether your Society would welcome the formulation of cooperative efforts with the Federation.

In the sincere belief that this type of program will render the greatest national and professional service, we look forward to having your comments on this proposal.

Half of the organizations have replied, with varying opinions on a cooperative program ranging from hearty acceptance to some doubt of its workability. The data will be studied and submitted for the guidance of the Federation at the Annual Convention.

There is much work to be done; our start has been modest and has been in word more than in action. However, we have already learned that prosecution of the outlined program of the Committee can protect and advance the status of the profession and establish the Federation as the national voice of a recognized profession.

Reviews and Abstracts

DEEP ENCLOSED ARTIFICIALLY VENTILATED FILTER BEDS VS. ORDINARY OPEN FILTER BEDS

By Cecil John Dekema and Kenneth Angus Murray

Public Health, 6, 8–22, No. 2 (February, 1942), Official Organ of the South African Branch of the Institute of Sewage Purification

In connection with the study of methods for the treatment of sewage from the towns of Germiston and Boksburg, South Africa, a large scale pilot plant employing parallel operated filters having the following characteristics was constructed.

	Enclosed Filter	*Open Filter*
Diameter	75 ft.	75 ft.
Total Depth of Media	12 ft.	6 ft.
Nature of Media	Crushed Witwatersrand Quartzite	Crushed Witwatersrand Quartzite
Size and Depth of Media		
Bottom Layer	4–6 in.; 1¼ ft. deep	4–6 in.; 1¼ ft. deep
Middle Layer	1–1½ in.; 9 ft. deep	1–1½ in.; 3 ft. deep
Top Layer	1½–2½ in.; 1¾ ft. deep	1½–2½ in.; 1¾ ft. deep
Nature of Structure	Reinforced concrete	Reinforced concrete
Nature of Ventilation	Forced draft downwards	Natural

Settled sewage was distributed to both filters by means of six-arm rotary distributors. Continuous forced downward ventilation for the enclosed filter was provided by means of 5,000 c.f.m. electrically driven centrifugal fan. An accurate air meter was provided. The volume of sewage fed each filter was measured by Venturi meters. The filters were matured by gradually increasing the dosage applied to both of them. Analytical results reported were obtained over a three year period. During this period, operation was continuous and sampling on any particular day was carried out throughout 24 hours. Maximum and minimum temperatures were measured at the top and bottom of both filters. Mean dosage rates over the three year sampling period were:

Enclosed filter, 221 gal./day/cu.yd. media
Open filter, 103 gal./day/cu.yd. media

Mean daily temperature readings for the three year period were:

	Bottom	Top
Enclosed Filter		
Maximum	70° F.	67° F.
Minimum	63	59
Open Filter		
Maximum	66	79
Minimum	56	47

The results indicate that the enclosed ventilated filter was able to treat to substantially the same degree of purity slightly more than 2.15 times as much of the same sewage per cubic yard of media as the open filter.

The air supplied to the enclosed filter was varied between 0.0 and 1.96 c.f.m. per cu. yd. media. The dosage rate varied between 111 and 438 g.p.d. per cu. yd. media. Results of operation indicated that there does not appear to be any determinable relationship between the quantity of air fed to the filter and its performance. However, there is a limit below which the operation of the filter is upset. Too great a fluctuation

Analytical Results

(P.p.m. except as noted)

	Oxygen Abs. in 3 min.	Chloride	Oxygen Abs. in 4 hours	Settleable Solids (c.c./liter)	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	5-day B.O.D.
Filter Influent	34.6	121	84.3	0.8	—	—	70	388*
Enclosed Filter								
Effluent	18.6	121	44.2	4.7	1.9	6.9	57	—
Effluent (S)	11.7	120	30.0	—	1.9	7.4	51	—
Effluent (F)	8.6	120	21.6	—	1.9	6.9	49	46
Open Filter								
Effluent	19.2	124	47.2	5.0	2.7	7.8	49	—
Effluent (S)	13.1	123	33.1	—	2.5	7.6	45	—
Effluent (F)	9.7	123	23.5	—	2.7	7.8	44	54

* Mean of last 9 months only.

(S) Supernatant after one hour's settlement in an Imhoff cone.

(F) Filtrate after filtration through Whatman No. 3 filter.

in the air supply affects the filter adversely. Increases or decreases should be held to about 10 per cent per day. For the conditions of this test efficient operation was obtained when the air supply varied from 1.53 to 1.78 c.f.m. per cu. yd. media.

Experience in the operation of the enclosed filter indicated that it is not free from filter flies. It was found that filter flies are able to work their way downwards through the media and escape through the outlet ducts in the false floor of the filter. Temperature conditions were favorable for active breeding of flies, particularly *Psychoda Alternata.* Filter fly breeding was controlled by systematic applications of chloride of lime to the surface of the enclosed bed. This treatment was also used in the case of the open filter.

Experience indicated that in general there was no objectionable odor associated with the operation of the enclosed filter.

The enclosed filter was found to be more stable toward volume and strength shocks than the open filter.

Maintenance and operation costs are discussed briefly but no cost data are given. Greater maintenance costs may be expected for an enclosed filter due to corrosive atmosphere around the distributor. Power consumption of fan and increased head, if sewage is pumped, add to operation costs but fly control by chloride of lime is less expensive for the enclosed filter. Deep enclosed filters occupy less ground than the conventional type.

PAUL D. HANEY

STUDIES IN MULTIPLE FILTRATION BY DEEP ENCLOSED ARTIFICIALLY VENTILATED BIOLOGICAL FILTER BEDS

BY CECIL JOHN DEKEMA AND KENNETH ANGUS MURRAY

Public Health (South African Publication), **6**, 8–25, No. 2 (March, 1942)

Following investigations of a deep, enclosed, artificially ventilated filter, a study of the action of multiple filters was undertaken. Two enclosed ventilated filters having diameters of 4 ft. and depths of 12 ft. were employed. The type, nature, arrangement and grading of media were identical to that used in the deep enclosed ventilated filter. (See preceding abstract.) Two rectangular settling tanks with hopper bottoms serving either filter were utilized (80–90 min. detention time for each tank).

Sewage distribution apparatus used in the two filters consisted of "vortex" garden sprays suitably modified to give even distribution.

Air supply was adjusted to conform to that supplied to the 75 ft. diameter enclosed filter discussed in a previous paper. (See preceding abstract.)

Analytical results obtained over a period of 2⅓ years are as follows:

Average Results

(P.p.m. except as noted)

	Oxygen Abs. in 3 min.	Chloride	Oxygen Abs. in 4 hours	Settleable Solids (c.c./liter)	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	5-day B.O.D.
Settled Sewage Applied to Filters	32.5	118	81.8	0.6	—	—	60	362*
Exp. Plant[1]								
Final Eff.	11.3	117	28.3	1.0	1.3	4.6	49	—
Final Eff. (F)	8.1	117	19.9	—	1.3	4.6	48	37
Enclosed Filter[2]								
Final Eff. (S)	10.8	118	27.4	—	1.1	8.3	45	—
Final Eff. (F)	0.8	118	20.0	—	1.1	8.3	44	43

(F) Filtered through Whatman No. 3 filter paper.
(S) Supernatant after 1 hour settlement in an Imhoff cone.
* Mean of last 14 months only.
[1] Two 4 ft. diam. filters 12 ft. deep.
[2] 75 ft. diam. filter, 12 ft. deep.

The mean filter loadings for the 2⅓ year period were:

Experimental plant (two 4 ft. diam. filters), 201 g.p.d. per cu. yd. media.
Enclosed filter (75 ft. diameter), 166 g.p.d. per cu. yd. media.

Changes in sequence of operation (reversals) of the two small filters in the experimental plant were studied. These changes in sequence involved transposition of the function of one filter as a primary to that of a secondary. The benefits of such an arrangement were considered to be (1) increased flexibility, (2) less likelihood of ponding. Controlled reversals, which consisted of adjusting loading by mixing of the normal influent to a filter with recirculated effluent, were found to be the most satisfactory.

Experience gained during this investigation indicated that large intermediate and final settling tanks are not required and may in fact be a detriment. It is believed that too great a degree of sedimentation results in failure of the secondary filter to build up sufficient active solid material on the media surface to give good purification. Supporting data are presented.

Operating results indicated that upward ventilation is slightly better than downward ventilation; however, more power is required for upward ventilation and there is more odor nuisance. It is concluded that in practice downward ventilation would prove the most satisfactory procedure.

Heating the ventilating air gave a slight but not significant improvement in performance. Heating is considered unnecessary.

On the basis that the purification capacity of a 6 ft. deep open filter gives a performance of 1.0, the authors calculate the performance ratios for the various arrangements studied as follows:

Enclosed ventilated filter (12 ft. deep) 2.3
Double filtration process using enclosed ventilated filters 12 ft. deep 3.2

PAUL D. HANEY

THE PURIFICATION OF SETTLED SEWAGE IN PERCOLATING FILTERS IN SERIES WITH PERIODIC CHANGE IN THE ORDER OF THE FILTERS. RESULTS OF OPERATION OF THE EXPERIMENTAL PLANT AT MINWORTH, BIRMINGHAM, 1938–1940

By J. M. Wishart and R. Wilkinsen

Read at the Annual Summer Conference at Manchester, July 3–4, 1941. To be published in the *Proceedings* of the Institute of Sewage Purification

The experimental filter consists of four circular trickling filters and four settling tanks of the upward flow type. Preliminary treatment of the sewage consists of grit removal, settling and a part of the flow is treated by bioflocculation process. The primary filter is supplied with sewage and the effluent is settled. The effluent from the settling tank is pumped to a secondary filter and settled again. Periodically the order of the filters is changed. The medium in the different filters consists of (1) slag and gravel, (2) gravel and broken bricks, (3) broken bricks and slag and (4) broken granite. The bulk of the medium will pass 2½ in. mesh and is returned on a 1 in. mesh screen. The detention period in each settling tank is 7 hr. at the rate of treatment of 100 gal. per day per cu. yd. of the filtering medium in the filter.

In the main biological filtration plant at Minworth the maximum rate of treatment is about 65 gal. per cu. yd. per day. At the rate of 60 gal. per cu. yd. per day the experimental filters operated by single filtration gave an average of about 20 p.p.m. B.O.D. in the effluent, and the variation in the effluents between the three filters was not appreciable. One filter was used per single filtration and the other two for double filtration with the order of the filters being changed every seven days. The double filtration was started at a rate of 60 gal. per cu. yd. of filter medium in the two filters together and was increased to 90, 120 and 160 gallons. In the control filter the rate of filtration was 60 gal. per cu. yd. per day and was increased to 70 and 80 gallons. When the rate of application in the single and double filters was 60 gal. per cu. yd. the B.O.D. of the settled effluent from the single stage filter was 7.5 p.p.m. and from the primary filter 12.5 p.p.m. and from the secondary 8.0 p.p.m. The results for subsequent periods are given in the table below:

Single Filtration Effluent

Rate*	B.O.D. P.p.m.	Rate*	B.O.D. P.p.m.	Rate*	B.O.D. P.p.m.	Rate*	B.O.D. P.p.m.	Rate*	B.O.D. P.p.m.	Rate*	B.O.D. P.p.m.
60	7.0	59	13.5	56	15.5	59	13.5	67	20.0	81	16.5
Double Filtration Final Effluent											
90	12.5	91	10.0	94	9.0	121	10.5	120	20.5	163	19.5

* Gal./Cu. Yd./Day.

Just before a change is made in the order of the filters there is a considerable amount of film on the surface of the primary filter and very little film on the secondary filter. When the order of the filters is changed the growth on the surface of the secondary filter rapidly disappears leaving only the algae. At the same time there is a considerable increase in growth on the surface of the primary filter. The disappearance of the film from the surface of the secondary filter takes place more rapidly in hot than in cold weather.

There was an increase in B.O.D. of the effluent from the secondary filter during the latter half of each week. The average B.O.D. for the first 2 or 3 days of the week was

14.5 p.p.m. and for the remainder of the week 24.5 p.p.m. The increase was not reflected, however, in the suspended matter and oxygen consumed value of the effluent. It was found that the diluted samples of the settled secondary effluent showing higher B.O.D. values had also a larger increase in the nitrate content than diluted samples from the primary or the single stage filters. The oxygen required to oxidize a part of the ammonia nitrogen in the effluent from the secondary filter to nitrite and nitrate was sufficient to account for a large part of the B.O.D. Similarly when the settled primary and secondary effluents increased there was a much greater increase of nitrites and nitrates in the secondary effluent than in the primary. It is suggested from these observations that the increase in B.O.D. of the secondary filter effluent during the second half of each week is due to nitrification. This phenomenon does not take place during the colder weather.

The suspended solids discharged from the single stage filter during one year operation was higher than that supplied. From the primary filter of the double filtration system the suspended solids discharged was lower than that supplied while from the secondary filtration system the suspended solids discharged was much higher. Taking the two filters together much more suspended solids was discharged than that supplied to the filter. The double filtration plant discharged solids more uniformly throughout the year than the single stage filter.

With a rate of application three times as high as in the single stage filter the B.O.D. of the effluent from the primary filter of double filtration plant one foot below the surface was almost the same as the effluent from single stage filter at the same level and was 60–70 per cent less than that of the settled sewage applied.

It was concluded that at least twice the volume of settled sewage per cubic yard of filtering material could be efficiently treated by double filtration system with periodic change in the order of filters as by the usual single filtration.

H. HEUKELEKIAN

THE TREATMENT OF SETTLED SEWAGE IN PERCOLATING FILTERS IN SERIES, WITH PERIODIC CHANGE IN THE ORDER OF THE FILTERS. BIOLOGICAL INVESTIGATIONS, 1938–1941

BY T. G. TOMLINSON

Read at the Annual Summer Conference at Manchester, July 3–4, 1941. To be published in the *Proceedings* of the Institute of Sewage Purification

The same types of organisms were in the filter used for single filtration as in those used for alternating double filtration, namely algae, fungi, bacteria, protozoa, Oligochaetae, insects, mites and spiders.

The dominant alga on the surface of the filters was *Chlorella*. *Ulothrix* was more dominant in the single stage filter and *Stigeoclonium* on the secondary filter of the double filtration plant but not on the primary filter.

Fusarium was the dominant fungus, both on the surface and within the filters. *Phoma* was found associated with *Fusarium* but not as abundantly. The most important fungus found in the filters was *Sepedonium*. It, however, cannot adhere firmly to, and grow unsupported, on a surface. *Oospora* was also found to a limited extent.

Paramoecium, Chilodon and *Colpidium* were the most frequent ciliates on the surface of the filters. *Lionotus, Amphileptus, Aspidisca, Euplotes,* and *Oxytricha* were found in the lower levels. *Vorticellae* were found in great numbers at all levels. There were more flagellates and amoebae in the upper than in the lower levels.

Achorutes viaticus was found in larger numbers on the surface of the secondary filter than on the surface of the primary filter but below the surface it was abundant in both filters. The activity of *Anisopus* larvae was one of the main factors in the sloughing. It was abundant in February and March at temperatures below the favorable range

for *Psychoda alternata*. After the middle of June the numbers of *Anisopus* rapidly decreased. *Psychoda* was most abundant during the summer and autumn.

The observations on the amount of film on the surface of filters showed that during the winter months the increase of film was less in the alternating double filters than in the single stage filter. In the double filtration much of the film in the surface was disintegrated and removed from each filter when the order of the filters was changed. Ponding was more extensive on the surface of the single filter than in the double filters, in spite of the higher rate of application on the latter.

It was stated that the growth of *Fusarium* on the glass slides placed on the surface of the secondary filters disintegrated due to physiological changes as a consequence of starvation. The disintegration of film on the secondary filter is caused in the first place by biological changes. The liquid then carries away particles of disintegrated solid matter.

H. HEUKELEKIAN

SOME ASPECTS OF MICROBIOLOGY IN THE TREATMENT OF SEWAGE

BY T. G. TOMLINSON

Journal of the Society of Chemical Industry, Transactions and Communications, **61**, 53–58, No. 4 (1942)

This paper deals with the occurrence of fungi on the experimental single and alternating double filters at the Menworek Works of the Birmingham, Tame and Rea District Drainage Board. The fungi found on the filters were: *Fusarium aqueductum, Oospora, Phoma* and *Sepedonium*. *Fusarium aqueductum* is the best known fungus occurring on sewage filters on account of the orange growth which it produces on the surface. It can grow in this location in spite of the force of the liquid striking the surface by virtue of hyphae which adhere firmly. When the order of the filters is changed the green algal growth on the primary filter in the course of a week of operation becomes covered with the orange grey color of the *Fusarium*. Changes in the reverse order occur on the secondary filter. *Oospora* occur in filters only below the surface of the double filters except in the winter when it forms part of the mat on the surface of the single filter. This may be due to the readiness with which the hyphae break up. *Phoma* is the first fungal colonist to appear on the surface of new filters. It does not produce large amounts of growth. When *Fusarium* becomes established it disappears or becomes a minor component. *Sepedonium* was found to be the most important fungus in the experimental filters at Minworth. It grows profusely on or below the filters during the colder months. It is, however, unable to withstand the greater force of liquid striking the surface of the filters at the higher rates of flow. Under these circumstances it grows in the subsurface zone and is responsible for the ponding. *Sepedonium* grew well on peptone and yeast preparation but not on ammonium sulfate, potassium nitrate, glycerine and asparagine. The optimum temperature for the growth of this fungus was about 21° C.

Glass slides were placed on the surface of the filters, one set of them being covered by glass covers and another by metal covers to protect them from light. The covers were constructed so that the amount of sewage impinging on the slides was the same. Examinations showed that *Fusarium* was dominant on the slides in the light and *Oospora* in the dark. It was concluded that *Fusarium* was able to compete successfully with *Stigeoclonium* and *Chlorella* for attachment on the surface of the slides in the light while *Oospora* was unable to do so. When algal growth was excluded by the exclusion of light, *Oospora* competed successfully with *Fusarium* and became dominant. It is suggested that the algae perform a useful function in limiting the growth of fungi on the surface of the filter.

In the alternating double filtration the fungus mycelium which has grown during the period when the filter is used as primary filter, gradually disintegrates during the

secondary period. It was found experimentally that the disintegration of the growth in the secondary filter was due to bacterial decomposition of the cell walls because when sterilized filter effluent was allowed to flow over a glass slide covered with fungus growths, the mycelium did not disintegrate while the growth disappeared when treated with non-sterilized filter effluent. An attempt was made to enrich and isolate the bacteria responsible for the decomposition of the fungi. The decomposition of the fungus growth was most rapid at 27.5° C. and slowest at 8° C. It is necessary, however, that the fungi undergo certain internal changes induced by starvation before the bacteria attack them.

H. HEUKELEKIAN

EXPERIMENTAL WORK TO IMPROVE THE PERFORMANCE OF A BIO-AERATION PLANT

By JOHN HIRST

The Surveyor, 101, 147–148 (May 1, 1942)

The author describes the results of experiments with chemical precipitation and pre-aeration, undertaken to increase the operating efficiency of the Haworth bio-aeration units of the Chesterfield sewage treatment plant. These units perform satisfactorily during seven months of the year when rainfall dilutes the sewage; during the remaining five (summer) months of dry-weather flow the activated sludge deteriorates and plant efficiency decreases. Observations over an extended period indicate that when the feed liquor to the bio-aeration units does not contain more than 5.5 parts per 100,000 of oxygen absorbed, the effluent complies with the standards set by the county council.

The sewage treatment plant at Chesterfield consists of detritus tanks and fine screens followed by primary sedimentation tanks having a capacity of 8 hours' dry weather flow. These likewise serve as storm water tanks. The primary tanks are followed by Dortmund type sedimentation tanks having approximately four hours' dry weather flow capacity. The effluent from these tanks is distributed between four Haworth bio-aeration units having a combined aeration capacity of 18 hours' dry weather flow, neglecting return sludge.

The bio-aeration units were designed for a dry-weather flow of 2,250,000 gallons per day, and now receive 2,750,000 gallons per day.

During the years 1939–40–41 primary sedimentation removed 41.9, 38.5 and 33.7 per cent, respectively, of the oxygen absorbed. Secondary sedimentation increased these removals to 44.8, 43.6 and 37.4 per cent.

The author states that the activated sludge produced is never very heavy. Typical good results are:

> Sludge by volume in mixed liquor after 1 hour's settling, 10 per cent.
> Sludge by weight in mixed liquor after 1 hour's settling, 0.075 per cent.

Figures of 35 to 40 per cent by volume and 0.08 per cent by weight are not uncommon during the dry summer months when the effluent is poor.

In order to obtain an oxygen absorbed figure of 5.5 parts per 100,000 in the sewage fed to the bio-aeration units, 50 to 55 per cent removals by chemical precipitation would be necessary. The author conducted laboratory experiments using anhydrous ferric chloride, "ferri-sul" commercial aluminoferric, ferrigel and sulfuric acid. Large quantities of the first three precipitants were found necessary to secure desired results, making the cost for their use prohibitive. Sulfuric acid alone was inadequate. Adjustment of pH with sulfuric acid and subsequent additions of ferric chloride and aluminoferric in quantities not excessive in cost did not produce desirable results.

Further experiments were made with ferrigel using ferric chloride and glue. At optimum precipitation a saving of 6 parts per 100,000 ferric chloride was obtained at the expense of 5.3 parts per 100,000 gelatine. A good heavy floc formed but the cost was excessive.

With pre-acidification to pH 6.0, an optimum of 55 per cent purification was obtained with 16 parts per 100,000 ferric chloride and 2.2 parts gelatine. On this basis, to precipitate Chesterfield sewage between 9 A.M. and 5 P.M. in summer would require 2 cwts. glue, 2 tons 70 per cent sulfuric acid and 1½ tons commercial ferric chloride per day.

Bottle aeration experiments on primary tank effluent indicated that one hour's aeration was sufficient to reduce the oxygen absorbed to the desired figure for treatment in the bio-aeration tanks. Ten per cent returned sludge was aerated with the primary tank effluent. Consideration is being given to converting the present secondary sedimentation (Dortmund) tanks to pre-aeration tanks for pre-aeration of the primary tank effluent and also for re-aeration of the sludge returned to the bio-aeration tanks.

K. V. HILL

CATALYTIC OXIDATION OF SULFITE WASTE LIQUOR BY ATMOSPHERIC OXYGEN

BY IRWIN A. PEARL AND HENRY K. BENSON

Ind. and Eng. Chemistry, **34**, 436 (April, 1942)

From a careful inspection of a large number of analyses of Puget Sound water in the vicinity of a pulp mill, it was found that when sulfite waste liquor is discharged into sea water, the immediate or chemical oxygen demand is most important of the three phases of oxygen demand exhibited by this type of waste. Once the chemical oxygen demand is satisfied, the slower biochemical oxygen demand exerted by the easily oxidized alcohols, sugars and acids on the one hand and the lignin on the other, is readily satisfied by the normal rate of absorption of oxygen by sea water from the atmosphere and from phyto-organisms.

This conclusion was substantiated by the results of an experiment in which variations of oxygen with time were observed in a solution of oxygenated water which was treated with digester strength sulfite waste liquor. Table I (taken from a graph in the original article) gives the results when 10 ml. of digester waste were added to 2,500 ml. of oxygenated water having a D.O. of 22.6 mg. per liter.

TABLE I

Time in Hours	0	0.25	0.5	0.8	1.0	1.6	2.0	3.5	35	75
D.O. mg. per l.	8.0	7.8	7.5	7.2	7.0	6.5	6.4	5.5	3.2	0

In order to stabilize this immediate oxygen demand before discharge into the water course, studies were made of catalysts for the atmospheric oxidation of sulfite waste liquor.

Preliminary tests had indicated that at room temperature the aeration of 10 per cent digester liquor by diffusion of air through a carborundum plate, had no effect in reducing the sulfite content of the liquor. Addition of a small quantity of oxidation catalysts such as copper sulfate, ferrous sulfate, manganese sulfate, and nickel sulfate likewise were ineffective. Aeration through spray nozzles also failed.

Temperatures were increased to 50° C. and 80° C. and the tests repeated.

Table II (taken from graph in original article) gives the results of these tests for the carborundum plate method.

TABLE II

Time in Hours	0	0.5	1.0	1.5	2.0	2.5	3.0
Ml. N/10 Iodine 50° C.	1.7	1.3	1.15	1.12	1.10	1.07	1.04
Ml. N/10 Iodine 80° C.	1.26	0.76	0.70				0.55

The data indicated that at higher temperatures, the sulfite content is reduced but not entirely removed.

The tower, which had been used for these aeration tests, was then filled with Alfrax porous pellets which had been impregnated with a number of catalysts. The 10 per cent digester liquor was introduced dropwise at the top of the tower counter-current to air introduced at the base at the rate of 1.2 cubic feet per hour. The liquor drained out at the bottom. The immediate chemical oxygen demand (I.C.O.D.) was determined on the aerated liquor and reported as milligrams of oxygen per liter of waste liquor. The effluent was recirculated and the I.C.O.D. determined. Table III gives the results of this test.

TABLE III

Catalyst	Per Cent Digester Liquor	Immediate Chemical Oxygen Demand			
		Mg. per Liter			
		Run 1	Run 2	Run 3	Control
Pt.	100	1327	1327	1327	1327
	10	134	134	134	134
Fe_2O_3	10	94	94	94	94
Cr_2O_3	100	1310	1148	977	1397
	10	41	22	14	131
CuO	10	95	72	61	135
MnO_2	10	54	0	0	134

The results indicate that this method of aeration in the presence of some catalysts was effective in removing the sulfite content from the liquor. Some difficulty was encountered due to solution of the oxide catalysts because of the acid nature of the waste.

Further tests using activated carbon, 6–8 mesh, in diameter, in the tower gave very satisfactory results. The advantage of the activated carbon over the oxide catalysts is its continued stability. It does not lose its activity after repeated use. The carbon seems to act as a carrier for oxygen, absorbing it and then relaying it in an active state to the substances in the liquor which are amenable to chemical oxidation, one of which is sulfites. The sulfite is stabilized to the sulfate in which state it can be discharged into the watercourse without danger of depleting the oxygen content.

E. HURWITZ

RECOVERY OF CHEMICALS FROM PICKLING LIQUOR AND COPPERAS WASTE

BY HARRY W. GEHM

Ind. and Eng. Chemistry, 34, 382 (March, 1942)

The pickling of steel and leaching of ores with sulfuric acid produces yearly over a billion gallons of waste consisting of solutions of ferrous sulfate and sulfuric acid. The discharge of these wastes into streams creates a serious pollution problem in some localities by depleting the oxygen content and producing conditions unfavorable to natural stream purification. Efforts to treat the waste have failed because of excessive cost. Recovery of ferrous sulfate from them is not economical and the market for the salt is rather limited. Recent trends toward solution of this problem has been in the direction of recovery of useful products other than ferrous sulfate.

The waste has been processed to produce Glauber's salt and a residue of iron oxide which is free from sulfur and from which iron can be recovered by treating the liquor with sodium silicate and soda ash.

The hot pickling liquor was stirred vigorously and sodium silicate (sp. g. 1.38, ratio $Na_2O : SiO_2 = 1 : 3.14$) poured in rapidly. Soda ash was then "spooned" in and stirring continued for 20 minutes to complete the reaction.

The precipitate filtered readily to a friable cake containing 65 per cent moisture. This dried on standing at room temperature for 30 hours to a powder having a moisture content of three per cent. Analysis of this powder showed that it was composed of 41.4 per cent ferric oxide and 39.1 per cent silica.

The filtrate contained 16.7 per cent sodium sulfate and yielded on evaporation Glauber's salt of the following analysis:

Sodium sulfate (Na_2SO_4)	99+ per cent	Manganese	none
Silica (SiO_2)	0.0014	Color	white
Iron (Fe)	none	Carbon dioxide	trace
Chlorides (Cl)	0.50	pH	8.5

Another series of experiments on processing this waste produced ferric chloride and a calcium sulfate with very good setting properties.

The pickling liquor was first treated with scrap iron to neutralize the excess acid and then sufficient calcium chloride in solution added to completely react with the ferrous sulfate:

$$CaCl_2 + FeSO_4 = FeCl_2 + CaSO_4 \downarrow .$$

Calcium sulfate was separated from the liquor by filtration on a Buchner funnel, washed with water and dried. Further processing of this cake produced a pure white calcium sulfate with very good setting properties. Another possible use for the calcium sulfate residue was its manufacture into a block for building purposes.

The filtrate contained ferrous sulfate which is easily converted to the ferric salt by chlorination. Recovery of iron averaged 87 per cent. The maximum concentration of ferric chloride solution obtainable by this process was 25 per cent. Present commercial processes produce solutions containing 40–45 per cent ferric chloride. However for a sewage treatment works within easy access to a source of waste pickling liquor this method of producing ferric chloride might be feasible and economical.

E. HURWITZ

SEWAGE DISPOSAL PROBLEMS AT ARMY CAMPS

BY PAUL HANSEN

American Journal of Public Health, 32, 181–186 (Feb., 1942)

Sewage disposal practice at army camps differs from municipal practice in the following important particulars: (1) army camp sewage is unaffected by industrial wastes and is relatively strong and high in grease. The per capita flow is generally less than in municipalities provided water use is properly controlled. (2) Plants are usually for temporary use only (assumed use, 5 years). (3) Speed in design and construction are essential.

As contrasted with the temporary nature of camp plants, those for permanent posts are designed and built for permanency.

Camps vary in size from 1,500 to 60,000 men, but the majority fall in the range of 12,000 to 36,000.

Records of army camp sewage analyses were meager but those available suggested the following characteristics:

	P.p.m.	Lb. per Capita per 24 Hours
Suspended solids	460	0.27
B.O.D. (5 days)	290	0.17
Ether soluble matter	150	0.09

Based on considerations of public health and prevention of *serious* nuisance it was recommended that when the minimum average monthly flow in the receiving water body is equal to or greater than 4 c.f.s. per 1,000 tributary population, primary treatment plus chlorination be provided. For lower flows secondary treatment was recommended. High rate trickling filters with chlorination offer the advantage of low construction cost and are considered adequate, even when dilution is limited.

Loadings on various plant units were recommended as follows:

Primary Sedimentation Tanks.—Detention time, 3 hours at average flow or 1.5 hours if followed by activated sludge. With recirculation of high rate filter effluent to tank inlet the tank volume is correspondingly increased.

Trickling Filters.—For high rate filters located in the south not over 3,000 lb. of B.O.D. per day per acre-foot, or a population load of 35,000 per acre-foot. For northern camps, not over 30,000 population per acre-foot. Standard filter, population loadings are 5,000 and 4,000 per acre-foot, respectively.

Final Sedimentation Tanks.—Not more than 800 g.p.d./sq. ft. based on average flow and not less than 2.25 hours detention time. With recirculation the capacity would be correspondingly enlarged.

Sludge Digestion Tanks.—Two to 3 cu. ft./capita for heated tanks. Increase 25 to 50 per cent for unheated tanks. For activated sludge increase these figures 50 per cent.

Sludge Drying Beds.—For standard sand beds use 0.5 to 1.0 sq. ft. per capita for dry southerly climates, and 1.0 to 1.5 sq. ft. per capita for humid northerly climates. In warm dry climates in favorable locations lagoons may be used with areas of 2 to 3 sq. ft. per capita.

The author closes with the suggestion that since operation and management of camp utilities are essentially civilian activities it would be desirable to man all water and sewage treatment works with qualified civilian operators whose efforts should be coordinated by a central agency in Washington.

PAUL D. HANEY

LOCAL ASSOCIATION MEETINGS IN 1942

Association	*Place*	*Date*
California Sewage Works Association	Los Angeles, Cal. (Hotel Clark)	Sept. 20–22
Canadian Institute of Sewage and Sanitation	Toronto, Ontario (Royal York Hotel)	Oct. 22–23
Missouri Water and Sewerage Conference	Hannibal, Mo.	October
New England Sewage Works Association	New London, Conn. (Ocean Beach Pavilion)	Sept. 25
North Carolina Sewage Works Association	Durham, N. C. (Washington Duke Hotel)	Nov. 2–4
North Dakota Sewage Works Conference	Williston, N. D. (Great Northern Hotel)	Sept. 21–23*
Ohio Sewage Works Conference	Cleveland, Ohio (Statler Hotel)	Oct. 22–24*
Rocky Mountain Sewage Works Association	Cheyenne, Wyo.	Sept. 16
South Dakota Water and Sewage Works Conference	Huron, S. D. (Marvin Hughett Hotel)	Sept. 28–29

FEDERATION OF SEWAGE WORKS ASSOCIATIONS *

Third Annual Meeting, Statler Hotel, Cleveland, Ohio
October 22–24, 1942

* Date changed from that previously announced.

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SECRETARIES OF MEMBER ASSOCIATIONS

Association	*Secretary*	*Address*
Arizona Sewage and Water Works Association	Richard Bennett	City Water Dept., Phoenix, Arizona
California Sewage Works Association	Jack H. Kimball	Orange County Health Dept., Box 355, Santa Ana, California
Central States Sewage Works Association	John C. Mackin	c/o Nine Springs Sewage Treatment Plant, Rt. 4, Madison, Wisconsin
Dakota Water and Sewage Works Conference		
(North Dakota Section)	K. C. Lauster	c/o State Dept. of Health, Bismarck, North Dakota
(South Dakota Section)	E. R. Mathews	Div. of San. Engr., State Board of Health, Pierre, South Dakota
Federal Sewage Research Association	R. S. Smith	U. S. Public Health Service, East Third and Kilgour Sts., Cincinnati, Ohio
Florida Sewage Works Association	J. R. Hoy	404 Hildebrandt Bldg., Jacksonville, Florida
Georgia Water and Sewage Association	T. T. Gunter	c/o Water Filtration Plant, Atlanta, Georgia
Iowa Wastes Disposal Association	L. J. Murphy	Iowa State College, Ames, Iowa
Kansas Water and Sewage Works Association	Lewis A. Young	1708 Mississippi St., Lawrence, Kansas
Maryland-Delaware Water and Sewerage Association	J. H. Schilpp	State Dept. of Health, 2411 N. Charles St., Baltimore, Maryland
Michigan Sewage Works Association	R. J. Smith	Mich. Dept. of Health, State Office Bldg., Lansing, Michigan
Missouri Water and Sewerage Conference	Warren Kramer	State Board of Health, 200 Monroe St., Jefferson City, Missouri
New England Sewage Works Association	LeRoy W. Van Kleeck	State Dept. of Health, State Office Bldg., Hartford, Connecticut
New Jersey Sewage Works Association	John R. Downes	P. O. Box 11, Dunellen, New Jersey
New York State Sewage Works Association	A. S. Bedell	c/o State Dept. of Health, Albany, New York
North Carolina Sewage Works Association	R. S. Phillips	P.O. Box 1170, Durham, North Carolina
Ohio Sewage Works Conference Group	W. D. Sheets	240 Binns Boulevard, Columbus, Ohio
Oklahoma Water and Sewage Conference	H. J. Darcey	State Dept. of Health, Oklahoma City, Oklahoma
Pacific Northwest Sewage Works Association	Fred Merryfield	Civil Engineering Dept., Oregon State College, Corvallis, Oregon
Pennsylvania Sewage Works Association	Bernard S. Bush	Pennsylvania Dept. of Health, Kirby Health Center, Wilkes-Barre, Pennsylvania
Rocky Mountain Sewage Works Association	Dana E. Kepner	1921 Blake St., Denver, Colorado
Sewage Division—Texas Section, S. W. W. A.	V. M. Ehlers	State Dept. of Health, Austin, Texas
The Canadian Institute on Sewage and Sanitation	A. E. Berry	Sanitary Engineering Div., Ontario Dept. of Health, Toronto Ontario, Canada
Sanitary Engineering Division of Argentine Society of Engineers	Carlos Santos Rossell	Centro Argentino de Ingenieros, Cerrito, 1250, Buenos, Aires, South America
The Institute of Sewage Purification—England	J. H. Garner	28 Aberford Road, Wakefield, Yorks., England
The Institution of Sanitary Engineers—England	Mrs. E. M. Kerry (Acting)	118 Victoria St., Westminster, S.W., 1, England

Any individual desiring to affiliate with the Federation as an Active Member, may do so by joining one of the Member Associations listed above. Write to the Secretary for particulars.

ADVERTISERS' CONTRIBUTIONS

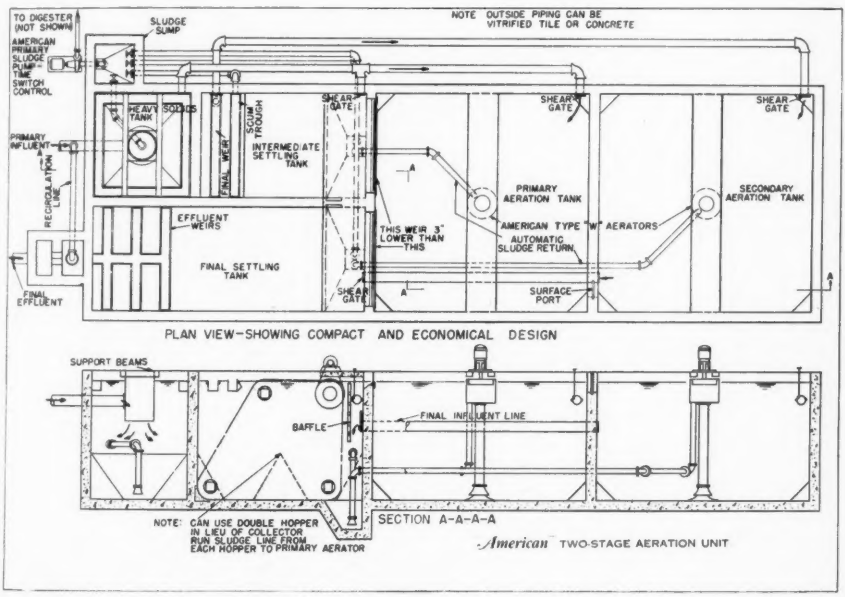
THE AMERICAN WELL WORKS

Aurora, Illinois

MANUFACTURERS OF PUMPING, SEWAGE TREATMENT, AND WATER PURIFICATION EQUIPMENT

RECENT DEVELOPMENTS IN ACTIVATED SLUDGE PLANT DESIGN TWO-STAGE AERATION

Two-stage aeration is an activated sludge process in which the aeration tanks are in series, or two stages, separated by a settling tank. The basic form is shown on the following flow sheet.



The heavy solids tank (primary settling) is designed on an extremely short detention period. The desire is to remove only that portion of the settleable solids that will come down in a few minutes of quiescence.

The primary aeration stage is designed as one-half of the total aeration capacity. Return activated sludge derived from the intermediate settling tank is continuously returned to this unit, which also acts as a grease flotation unit. This will protect the second stage aeration and its activated sludge from harm that would otherwise cause a biological upset. The intermediate settling tank is designed to settle all solids flowing from the first stage.

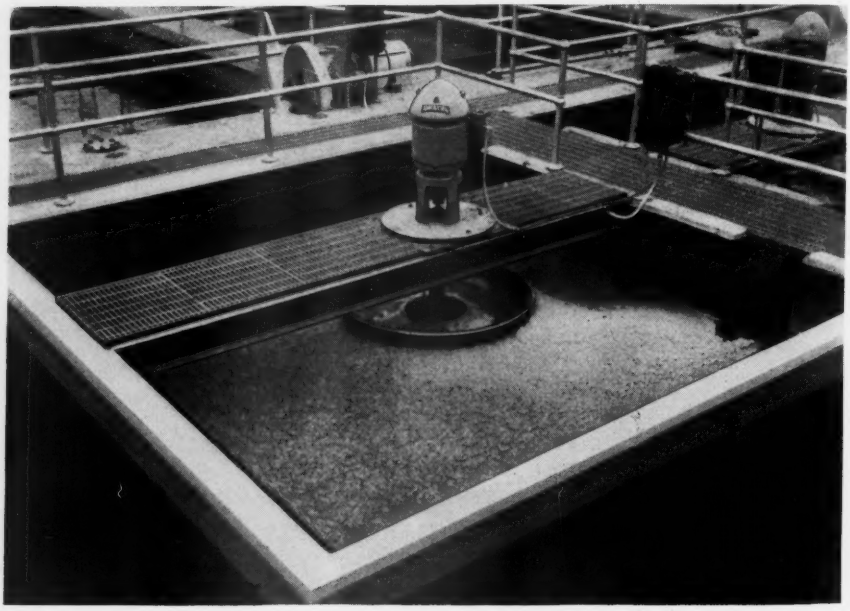
The second stage aeration and the final settling are designed and operated much the same as any standard activated sludge process.

We believe the two-stage process is more efficient and less subject to upsets than the standard activated sludge process. An important feature is the recirculation of large quantities of final plant effluent, carrying enzymes and dissolved oxygen.

Two-stage aeration is an evolution or improvement in the older style pre-aeration and grease flotation followed by activated sludge. The improvements are a short detention period ahead of the pre-aeration stage and a return of intermediate settling tank sludge to the pre-aeration stage to act as a nucleus to increase the effectiveness of that unit. If anything happens to the sludge in the first stage of aeration, such as introduction of an abnormal quantity of grease, the sludge will be lost but the final stage will not be affected, whereas in a standard activated sludge process, any harmful substances passing through the primary settling tank will immediately exert a detrimental effect on the entire inventory of activated sludge and the whole plant will be adversely affected.

REMOVAL OF GREASE FROM SEWAGE

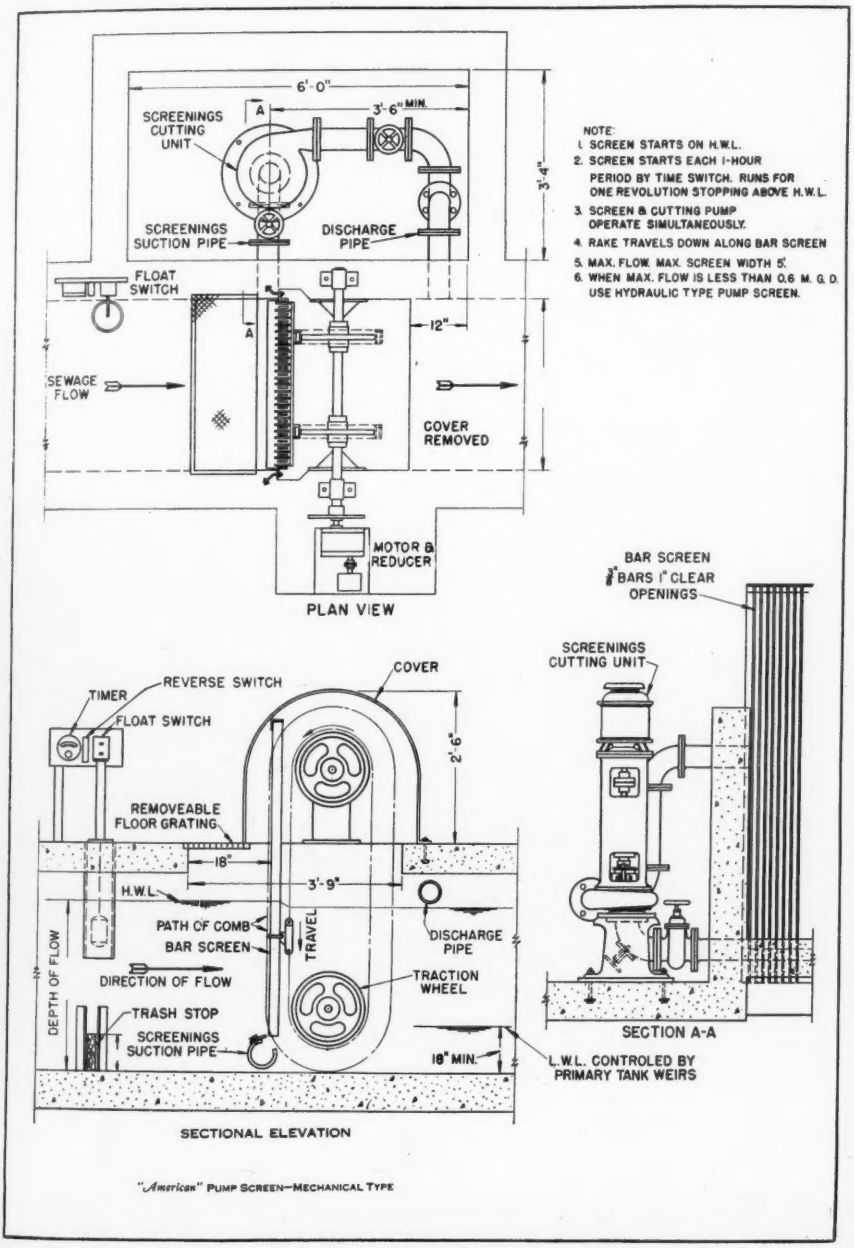
Under present conditions many plants, particularly cantonments and industrial plants, have unusually large amounts of grease in the sewage. In cantonments this comes from the kitchens which waste large amounts of grease. Very often, grease traps provided are either too small or are not cleaned regularly.



The grease is intimately mixed with the sewage in flowing through the sewers, part becoming a colloidal suspension and part dissolving. It is impossible to remove this in the settling tanks and it is carried into the secondary treatment or into the stream if no secondary treatment is utilized. The effect of grease on any type of biological secondary treatment is detrimental. In trickling filter

plants the grease coats the filter media. In activated sludge plants the grease is absorbed by the floc and causes the floc to become light and to flow over the effluent weirs.

The American Well Works has developed a unit particularly adapted for the



"American" PUMP SCREEN—MECHANICAL TYPE

removal of grease by the air flotation method. In this method mechanical agitation is combined with the injection of minute air bubbles at the bottom of the tank surface. The beneficial agitation causes the grease to accumulate and to become entrained with the very fine air bubbles. The grease particles rise to the surface of the tank, forming a blanket of scum. This scum may be either automatically or hand skimmed.

This grease flotation unit is placed ahead of the primary sedimentation tanks since the grease removed has much suspended solids entrained in it.

Since this unit requires no head loss to operate, it can be added to any existing plant.

SCREENINGS DISPOSAL

We have developed a pump screen which automatically removes objectionable solids from the waste flow, conducts these solids to a cutting unit and discharges the disintegrated solids either into the sewage flow, or into the digester.

The unit consists of a vertical bar rack (of any desired spacing) cleaned downwardly by downstream cleaning fingers extending through the screen bars, operating simultaneously with a cutting pump. The fingers on the rake push the screenings into a trough at the screen base which feeds the cutting unit. The cutting unit minces the screenings into fine particles which will not cause a nuisance.

The pump screen is applied either before or after the grit channel, since grit does not injure the cutting unit. Because it is preferable to have screening ahead of grit units, the pump screen is generally placed in that position. Large variations in flow can be handled without either causing a flood ahead of the screen at high flows or detracting from the cutting efficiency of the cutting pump at low flows. Also, the cutting unit and screen operate only 3 per cent of the time. Thus, wear is kept to an absolute minimum. The cutting pump impeller is hollow ground and consequently is self sharpening.

This pump screen unit will successfully solve the screenings problem in any plant, and leave the operator free to perform more important plant duties.

THE CARBORUNDUM COMPANY

Niagara Falls, N. Y.

MANUFACTURERS OF POROUS AIR DIFFUSER PLATES AND TUBES (ALSO POROUS UNDERDRAIN PLATES, ABRASIVES AND REFRACTORIES)

Concurrent with the conception and original development of activated sludge treatment, various methods of aeration were tried. Two general trends followed; air diffusion for larger plants and mechanical aeration for smaller plants. Just recently efficient air diffusion has extended to even the smallest plants when applied with the equipment offered by Chicago Pump Company.

For air diffusion, the cycle of equipment development passed through trials of perforated pipe, porous wood and miscellaneous materials until the ceramically bonded inert granular material such as composes Aloxite Brand Diffusers was offered. This type of diffuser has since become relatively standardized at a medium-coarse grade (40 permeability) although other grades are available for aeration applications other than activated sludge treatment.

The 40 permeability grade referred to provides plates of relatively low pressure loss and fairly open pores but maintains reasonably small air bubbles as is required for efficient oxygenation.

Aeration by air diffusion is now utilized in the following sewage treatment operations in approximate order of importance:

1. Activated sludge aeration.
2. Sedimentation pre-aeration (grease separation).
3. Chemical treatment, pre-aeration and mixing.
4. Channel aeration.
5. Chemical flocculation.
6. Trickling filter pre-aeration.
7. Sludge mixing.
8. Sludge elutriation.
9. Post aeration.
10. Grit washing.

The original porous diffuser for all applications was in the form of a flat plate. Various sizes of these have been used but 12 in. square plates have proved the most practical and have become more or less standard. Diffuser tubes were offered later because they can be serviced and handled more economically. However it was not until recent years that the high efficiency of aeration by diffuser tubes was proved. Tubes are now used successfully for all applications.

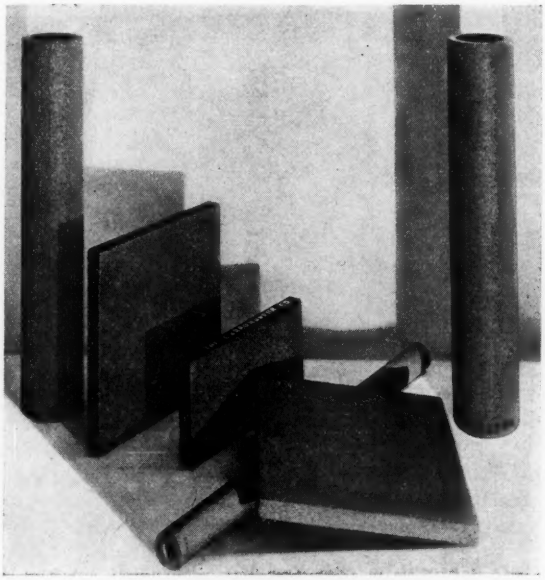


FIG. 1.—Aloxite Brand Diffusers.

The accompanying photograph illustrates some of the Aloxite Brand Diffusers now offered by The Carborundum Company. Standard plates are 12 by 12 by 1 in. thick and 12 by 6 by 1 in. thick. Canadian Carborundum Company, Ltd., also offers plates approximately 17¼ by 7½ by 1 in. thick which are assembled

in pairs in the type of cast iron diffuser plate holder normally used in Canada. Standard Aloxite Brand Diffuser Tubes are furnished in the following sizes:

4¼ in. O.D. by 3 in. I.D. by 24 in. long
3 in. O.D. by 2 in. I.D. by 24 in. long
1¾ in. O.D. by ¾ in. I.D. by 28 in. long

The most recent development in aeration by air diffusion, as referred to in the first paragraph, is the Chicago Pump Company method of installing tubes on one side of an aeration tank to retain "spiral flow" but in a position transverse to the center line as illustrated by the accompanying photograph. This development is proving to give the most efficient form of air diffusion in practice because of the wide band of air bubbles which are introduced. There is a minimum amount of coalescence of bubbles and consequent maximum absorption of oxygen. Also the advantages of simplicity in construction and operation (servicing) are retained with such use of diffuser tubes.

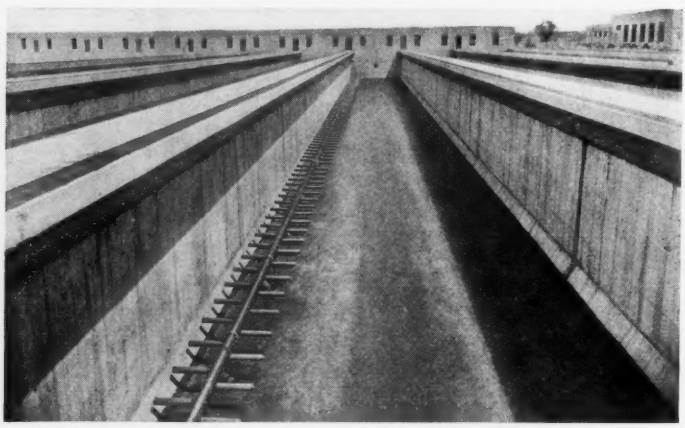


FIG. 2.—Diffuser Tube Arrangement. Chicago Pump Company.

Aloxite Brand Diffuser Tubes are offered by The Carborundum Company for this latest and most efficient method of aeration through Chicago Pump Company, Chicago, Illinois. For all other methods of aeration and replacement of worn out diffusers, all types of plates and tubes are sold direct. Data on all aeration applications and detailed diffuser information are available in the form of Engineering Bulletin No. 1. This will be forwarded on request to The Carborundum Company, Niagara Falls, N. Y.

RALPH B. CARTER COMPANY

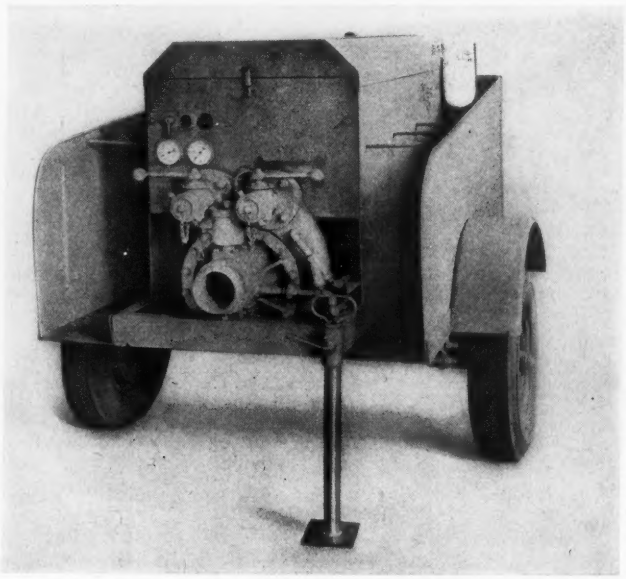
192 Atlantic St., Hackensack, New Jersey

MANUFACTURERS OF SLUDGE PUMPS, FLOCERS, CONDITIONERS, MIXERS, FILTERS, AERATORS, SIPHONS, WATER SYSTEMS, SELF-PRIMING CENTRIFUGAL PUMPS, HUMDINGER PUMPS

Foreseeing the necessity of a portable pump to combat the numerous fires started by incendiary bombs dropped by enemy raiders, the Ralph B. Carter

Company in 1940 began a series of test models that led to the development of the "CARTER CHIEF" and "CARTER WARDEN" Fire Fighters. These units, designed primarily for fire fighter service, are being used throughout our country at airports, shipyards, cantonments, institutions and industrial plants, not only for this service, but also as booster pumps for regular fire apparatus, and emergency water supply units in case of power failure. On the foreign front the "Carter Fire Fighters" have been shipped for use throughout the far flung battlefields of the five continents.

Of rugged and comparatively simple design, these units are of the trailer type, for easy towing behind a pleasure car, taxi or small truck, and are mounted on either rubber tires or steel wheels. Fully enclosed hose racks permit carrying 500 ft. of 2½ in. rubber-lined fire hose and two 12½ ft. lengths of 4 in. suction hose, on the "CHIEF," and the same amounts of suction and discharge hose in 1½ in. and 3 in. sizes, respectively, on the "WARDEN." If the user prefers 2½ in. discharge hose on the "WARDEN," this may be substituted in place of the 1½ in. up to a total of 250 feet.

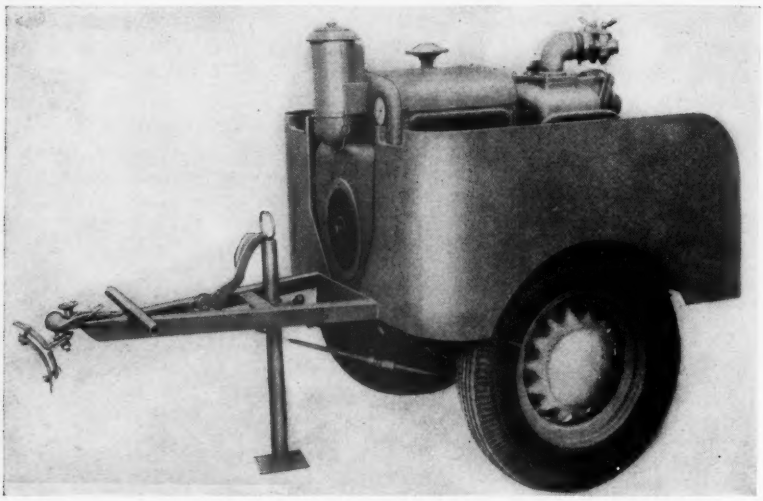


Carter "Chief." 500 G.P.M. at 120 lb. pressure, single stage, self-priming Chrysler engine, Carter type heat exchanger, self-starter.

The "WARDEN" model is of the single-stage type, completely self-priming with seal ring, while the "CHIEF" model is constructed in both the single and two-stage type with stuffing box.

Both units are completely self-contained and are provided with tool box and necessary tools. Front and rear stops are provided to keep the pump in horizontal position while in use and to permit uncoupling from the automobile or truck, which may be required for other service. The hitch between the pump and prime mover is accomplished with an automotive, ball-type trailer coupling. A hand brake is provided to prevent the unit from creeping while in operation or rolling when parked on grades.

The 1942 model of the "CARTER CHIEF," which has an Underwriters' approved rating of 500 g.p.m. at 120 lb. pressure, is built in both the single and two-stage types, with either radiator or heat exchanger cooling. Official tests on the above unit, using two 250 ft. lines of 2½ in. rubber-lined fire hose, with two 1¼ in. nozzles and 20 ft. of 4 in. suction hose, shows two 277-gallon per minute streams at 82 lb. pressure which throws streams 64 ft. vertically and 57 ft. horizontally.



Carter "Warden." Manufactured by Ralph B. Carter Company, Hackensack, N. J. Pump capacity, 150 G.P.M.; discharger pressure, 100 lbs.

The same unit using one 500 ft. line of 2½ in. rubber-lined fire hose, with a 1¼ in. nozzle and 20 ft. of 4 in. suction hose, shows one 360-gallon per minute stream at 200 lb. and 60 lb. nozzle pressure, which throws a stream 85 ft. vertically and 76 ft. horizontally.

The "CARTER WARDEN" has an approved rating of 150 gallons per minute at 100 lb. pressure. This pump at the above capacities and pressures throws a stream 79 ft. vertically and 60 ft. horizontally using one 250 ft. line of 2½ in. rubber-lined fire hose and one ¾ in. nozzle with 20 ft. of 3 in. suction hose. The same pump when fitted with two 250 ft. lines of 1½ in. rubber-lined fire hose with two ½ in. nozzles and 20 ft. of 3 in. suction hose, shows two 65-gallon per minute streams at 100 lb. pump pressure and 70 lb. nozzle pressure, and throws streams 70 ft. vertically and 50 ft. horizontally.

CHAIN BELT COMPANY

Milwaukee, Wis.

MANUFACTURERS OF REX CHAIN—REX CONCRETE MIXERS—REX SPROCKETS—REX TRAVELING WATER SCREENS—REX ELEVATORS AND REX CONVEYORS

ANOTHER REX AERO FILTER INSTALLATION IS COMPLETED

The month of March, 1942, brought to completion the new sewage treatment plant for the Village of Cokato, Minnesota. Designed by the well-known firm of

architects and engineers, Toltz, King & Day, Inc., the plant embodies the most modern principles of sewage treatment, with serious consideration having also been given to pleasing architectural appearance. Eye appeal was especially desirable in view of the proximity of the plant to existing and anticipated residences.

As their basis of design, the engineers selected the REX Aero-filter process, thus taking advantage of equipment of low first cost and low maintenance cost. The treatment plant was designed to permit gravity flow through the entire plant. The raw sewage is brought into the plant through a hand-cleaned bar rack and hand-cleaned grit chamber, and then into the primary tank equipped with REX mechanical equipment for the collection of sludge and skimming of the tank surface. From the primary tank the sewage flows to the Aero-filter, then to the final settling tank, also equipped with REX primary type sludge collecting equipment, then to a small tank for chlorination, when necessary, and finally to the river outfall. Provision has also been made for chemical conditioning of the sludge preparatory to running it onto housed sludge drying beds.

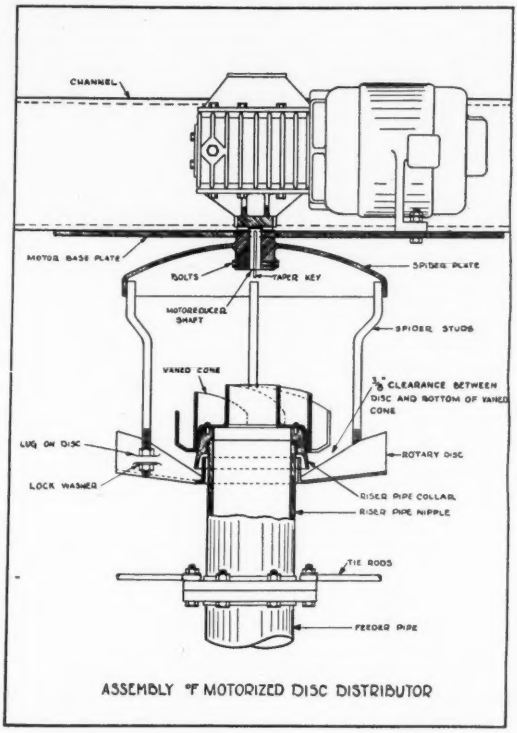


FIG. 1.

The Aero-filter is 20 ft. in diameter, with 6 ft. 6 in. depth of media and operates at a normal rate of 18 m.g.a.d. It is capable of taking flows up to 26 m.g.a.d. and will operate satisfactorily at a minimum flow of 9 m.g.a.d. Below this range, recirculation of plant effluent will be made, and a single recirculation pump has been provided to make this possible. The recirculation is taken from the effluent end of the final tank, just below the surface, and is discharged into the effluent

trough of the primary tank. The total drop between the water surface in the primary tank and the top of the top of the filter media is but 3 ft., and the total drop to the final tank is approximately 10 ft.

The distributor equipment itself is the new and improved REX motorized disc. All bearings have been eliminated except those within the drive unit itself, thus

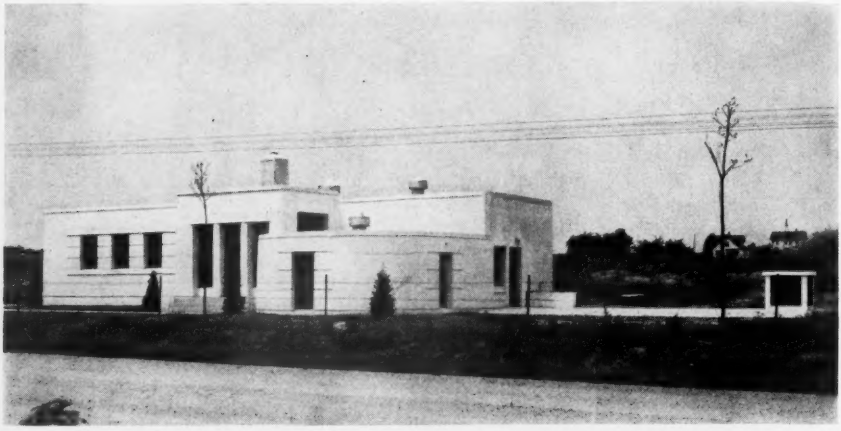


FIG. 2.

FIG. 3.

insuring trouble-free operation. The rain-like distribution necessary for maximum performance of high capacity filters is assured at all rates of flow with this type of distributor. A drawing of the distributor assembly (Fig. 1) appears on page 1171.

The disc assembly consists of three parts: the pipe collar, the static (vaned) diffuser, and the revolving disc. The collar is fastened on top of the vertical feed pipe and has a skirt which overlaps the inner flange of the disc. The construction makes a mercury seal unnecessary. The curved vane diffuser rests on top of the collar and guides the sewage onto the rotating disc, in the direction of rotation. This permits the disc to pick up and throw out the sewage with a minimum of disturbance. It also results in low power consumption. The disc is cast with radial vanes of varying length and height so that the sewage is evenly distributed over the entire bed. A disc distributor of this type can be used in Aero Filters up to and including 34 ft. in diameter.

Figure 2 is an external view of the plant. The building wing to the left houses the sludge drying beds with the garage and sludge disposal room located immediately to the rear. The entrance to the building leads into the control room, below which is the pump room. The right wing of the building at the rear houses the primary tank, and the circular bay projecting out from the front of the building houses the Aero-filter. The final tank is to the right of the building beneath the concrete slab at ground-line. The cupola at the far right is located immediately above the chlorine detention tank.

Figure 3 is an interior view of the Aero-filter room, looking towards the window on the right. Only the drive unit of the motor driven disc distributor is visible. The unit was in operation when the picture was taken but because of the excellent distribution of sewage no particles in motion are apparent. Note the use of "Aero-drane" filter media.

CHICAGO PUMP COMPANY

2300 Wolfram Street, Chicago, Illinois

AIR DIFFUSION SYSTEMS WITH SWING DIFFUSERS AND STATIONARY DIFFUSERS, COMMINUTORS, SCRU-PELLER PRIMARY SLUDGE PUMPS, FLUSH-KLEEN SEWAGE LIFT STATIONS, COMBINATION AERATOR-CLARIFIERS, RAW SEWAGE PUMPS, PLUNGER SLUDGE PUMPS AND WATER SEAL PUMPING UNITS

During the last ten years the Chicago Pump Company has concentrated its effort on the activated sludge process for complete treatment of sewage, and it is today the only sewage equipment manufacturer wholly specializing in the application of this process. Moreover, the Chicago Pump Company has applied its equipment to a greater number of activated sludge plants than any other manufacturer.

The activated sludge process data and actual operation records compiled by the Chicago Pump Company are used as a basis for complete recommendation reports on the application of "Chicago" equipment.

More than 150 "Chicago" equipped activated sludge plants are in successful operation. The plant operators of nearly all of those plants were trained by Chicago Pump Company operating sanitary engineers to produce a consistently high degree of purification under widely varying sewage flows and strengths.

"Chicago" air diffusion system with stationary diffuser tubes at the Gary, Ind., sewage treatment plant. The air main and the tube holder are combined in a single pipe.

"Chicago" air diffusion system with swing diffusers at the Omaha, Neb., sewage treatment plant. Each swing diffuser unit can be raised completely out of the tank for tube inspection, maintenance and regulation of air supply without dewatering the tank or interrupting operation.

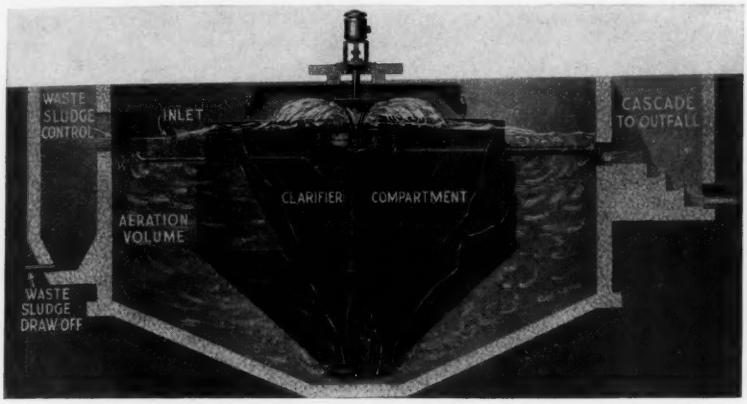
"CHICAGO" AIR DIFFUSION SYSTEMS

A wide band of air diffusion perpendicular to the line of sewage flow is provided by the elevated diffuser tubes of the "Chicago" air diffusion systems with either swing diffusers or stationary diffusers. The wide band gives a greater contact volume of diffused air with the tank liquor, a longer contact time of air bubbles in the tank liquor and a uniform spiral circulation with thorough mixing. There is no unaerated center core. The actual aeration period is close to the calculated detention, due to the elimination of short circuiting. The hydrostatic head for air pumpage is decreased 15 to 20 per cent by the location of tubes. A higher rate of air delivery per diffuser is obtained without coalescence, due to the wiping action of liquor rising from beneath and between the tubes. The same rate of air delivery from each tube, regardless of standard permeability variations, is insured by control orifices. The installation and removal of tubes is simple and quick.

Swing diffusers can be raised completely from the aeration tank by means of an electric hoist. Tube inspection, maintenance and regulation of air supply can

all be accomplished from the tank walk without dewatering the tank or interrupting operation.

The stationary diffuser aeration system combines the air main and tube holder in a single pipe mounted above the floor of the aeration tank.



"Chicago" combination aerator-clarifier which performs the aeration, clarification and waste sludge control phases of the activated sludge process in a single tank. This unit has proved itself ideal for small camps and housing projects.

COMBINATION AERATOR-CLARIFIERS

Combination aerator-clarifiers were developed by the Chicago Pump Company to make it possible for institutions and small towns to obtain the advantages of the activated sludge process for the complete treatment of their sewage at low construction cost. This equipment has recently proved itself ideal for small camps and housing projects. It performs the aeration, clarification and waste-sludge control phases of the activated sludge process in a single tank.

DE LAVAL STEAM TURBINE CO.

Trenton, N. J.

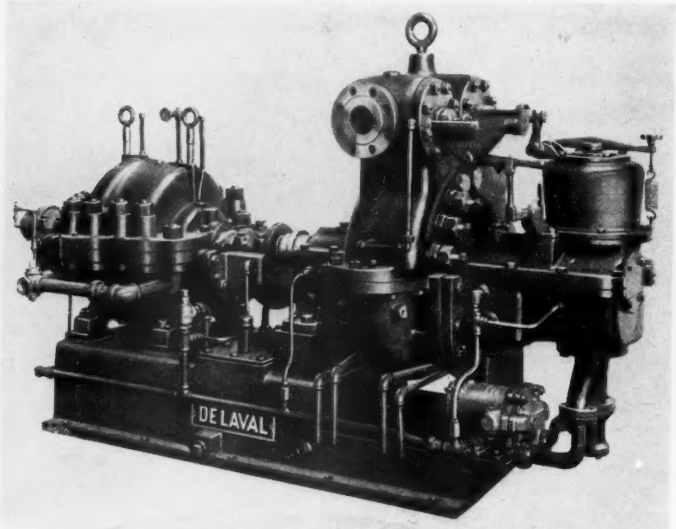
DE LAVAL VELOCITY-STAGE TURBINES

The De Laval velocity-stage turbines herewith shown have been designed to meet modern conditions of steam pressure and temperature. Where used for driving auxiliaries, such as pumps and fans, they can in most plants be connected directly to the superheated steam main. The efficiency is as high as is attainable with a single-pressure stage and where the exhaust steam is utilized for heating and process purposes high overall economy is had.

Steam expands from the initial to the final pressure in a single set of nozzles. The latter are made of stainless steel, accurately machined and reamed. They are screwed and welded into drop-forged steel bodies supported by the steam chest wall. Hand valves for individual nozzles can be fitted to make possible high efficiency under varying load or steam conditions. The steam is directed onto a first row of stainless steel buckets, which are individually fastened to the wheel. From these buckets it enters between stationary stainless steel guide

vanes, integral with and supported by the nozzles, which redirect it onto a second row of moving buckets, also of stainless steel. The buckets have large radial and axial clearances.

The casing cover combines in one casting the steam chest and the speed-governor and emergency shut-off valve bodies. These parts, and the nozzles, are the only parts of the turbine coming into contact with steam at the initial pressure and temperature and, where the pressure and temperature of the steam are high, they are made of cast steel. The lower half of the casing is also made of cast



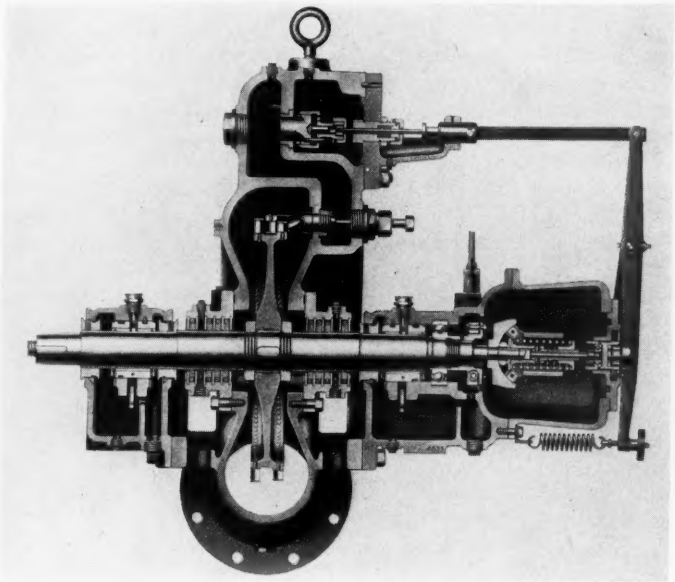
Velocity-stage turbine with vertical governor driving a four-stage boiler feed pump

steel where required by high-temperature exhaust conditions. The cover and attached parts are easily lifted to expose the wheel. There are no packed joints or cross-over connections to the lower half of the casing. Parts subject to the highest temperatures are remote from and above the shaft and bearings, resulting in lower temperatures of bearings and oil. For moderate steam temperatures the babbitt-lined bearings are lubricated by rings which carry up oil from reservoirs, but where the temperature of the steam at inlet or at exhaust is excessive, water-cooling or forced-feed lubrication can be provided. Also, an oil pump is provided for forced-feed lubrication in high-speed turbines. The cast iron bearing shells are accurately machined and ground to fit seats accurately scraped to limit gages. A ball thrust bearing locates the rotor axially.

The wheel is machined from a steel forging and is proportioned to withstand rotating speeds far in excess of normal. It is held by key and lock nut upon a shaft of liberal size. Steam or air leakage is prevented by packings on the shaft at each side of the casing. Each packing box contains four carbon rings, with an intervening space for steam-sealing or bleed-off.

The turbine has a centrifugal speed governor and an independent emergency tripping device consisting of an eccentrically loaded, pivoted ring which, at a predetermined speed, releases the independent emergency shut-off valve, which has a stainless steel stem. The valve can also be tripped and reset by hand.

The powerful and sensitive speed-regulating governor, consisting of fly-weights pivoted upon rockers, is either mounted on the turbine shaft or, depending upon operating conditions, on a vertical shaft driven through a worm and worm wheel. The governing action is transmitted to the regulating valve through a ball thrust bearing and a lever mounted on a needle bearing. By adjusting a spring the speed can be changed while the turbine is running. Hydraulic governors also are used, particularly where the speed of the turbine is to be regulated to control



Section of velocity-stage turbine with shaft governor.

the pressure or the rate of flow set up by a pump, a blower, or a compressor. The regulating valve is of the balanced, seating type and is actuated through a stainless steel stem packed with pure asbestos rings. The emergency closing and governor regulating valves are preceded by an accessible and removable steam strainer, consisting of a heavy, monel-metal screen.

The parts for these turbines are manufactured in quantities, using special jigs, gages and fixtures, and are inspected by means of limit gages to insure interchangeability and to eliminate hand-fitting. Each part is marked with symbols to certify inspection and for identification when ordering a duplicate part. After assembly a running test is made of each unit to insure satisfactory mechanical operation.

THE DORR COMPANY, INC.

570 Lexington Ave., New York, N. Y.

RECENT DEVELOPMENTS IN THE SEWAGE WORKS FIELD

During the past year our efforts in the sewage treatment field have been devoted almost entirely to supplying equipment for plants for military camps and

bases. Some new designs, however, have been developed to meet the specific requirements of the military engineers. These designs range from the development of complete new units, such as the Vacuator for grease and scum removal, to those aiming at the reduction of critical materials in the individual items of equipment. Attention has also been focused on the Biofiltration System with the object of obtaining greatest efficiency at a minimum cost. The Ward Process has been developed for use in Biofiltration.

VACUATOR

The Dorreo Vacuator is a machine devised to remove grease, scum and oil from sewage or trade waste by vacuum flotation ahead of sedimentation. The sewage is aerated for a brief period and the aerated liquor is then subjected to a vacuum equal to several inches of mercury for a period of 10 to 15 minutes. The fine bubbles attach themselves to the grease or scum-forming particles, causing them to rise to the surface under the influence of the vacuum. The grease and scum are skimmed continuously by revolving arms to a radial trough outlet. The effluent is discharged over weirs at the periphery into a water seal, to avoid breaking the vacuum, and continues to the customary sedimentation units. The vacuum pump required is very small as its only work, once the tank is filled, is to remove entrained air from the tank contents.

Four full-scale installations are under construction or operation at this time.

WARD PROCESS WITH BIOFILTERS

The Biofiltration System includes, among other things, recycling biofilter discharge back to the clarifier in single or multiple-stage systems. In addition to this we now have added the Ward Process which includes, among other things, recycling the final clarifier contents or effluent back to the biofilter influent. With the combination of the Ward Process and the Biofiltration System, a simple arrangement can be used in a single stage plant. The flowsheet shown in Fig. 1 is the one recommended. Results which equal those from a two-stage plant can be obtained in this single-stage arrangement. Primary and final clarifiers are identical in size, which simplifies construction.

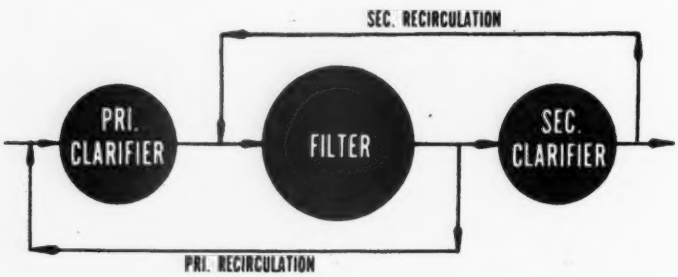
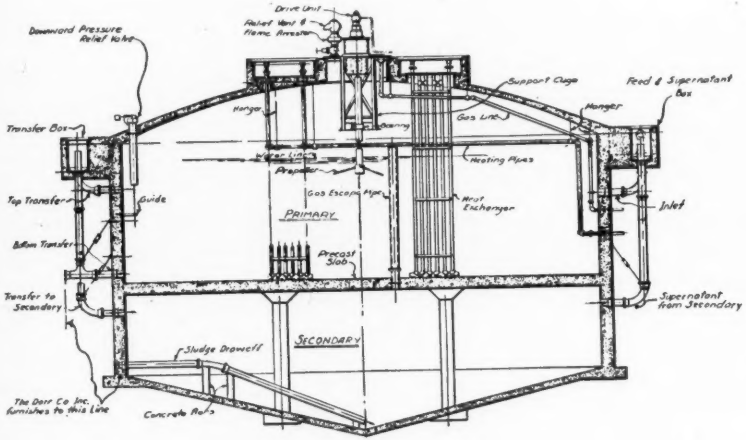


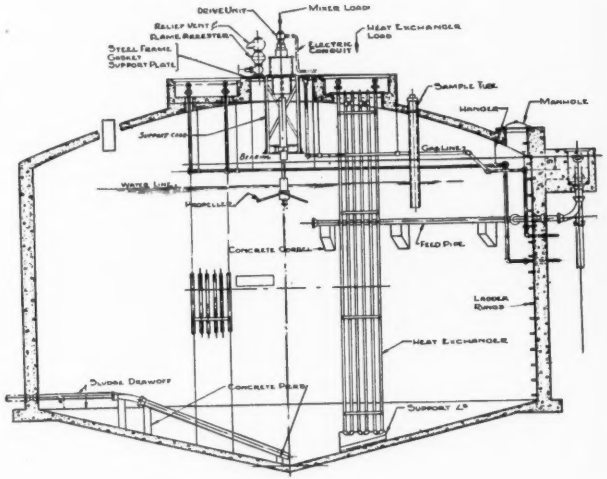
FIG. 1.—Flowsheet single stage biofiltration with Ward process.

The interest in Biofilters continued unabated with the results that the number of plants placed under construction during the past year is more than twice the total number previously installed. A typical Biofilter Plant for an Air Base is shown in Fig. 2.



SECTIONAL ELEVATION

FIG. 2.—Dorr multdigester.
Two-stage unit.



SECTIONAL ELEVATION

Dorr digester.
Single stage.

SLUDGE DIGESTION

We are offering two new units (see Fig. 3) in this field, both being designed to conserve critical materials. Steel plate has been eliminated and piping simplified, but all other features are retained except gas storage. Gas storage does not appear essential for military installations.

The Dorr Multdigester is a two-stage system but in one tank instead of two, as in the standard Multdigestion System. The Multdigester is a single tank with an upper compartment for primary digestion and a lower compartment for second stage. Mechanical mixing and vertical heat exchangers, both removable while operation continues, are provided in the primary stage. Automatic sludge transfer from primary to secondary stages is provided and automatic supernatant withdrawal from the secondary stage completes the cycle.

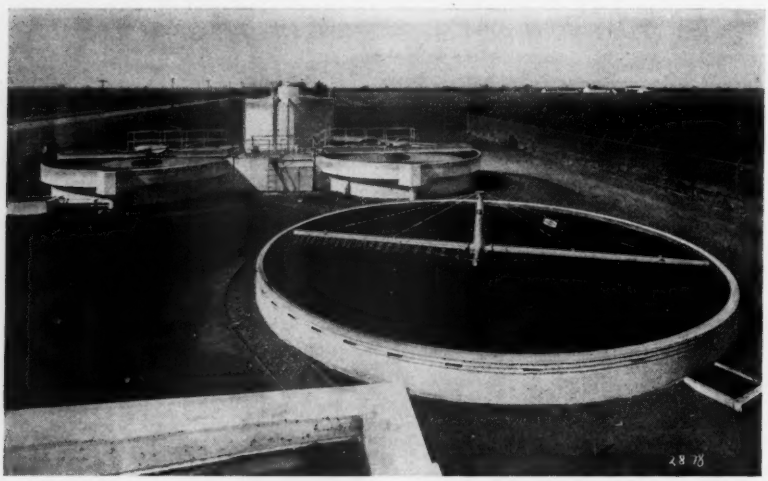


FIG. 3.—Army camp type of biofilter plant.

One important feature welcomed by every operator has been incorporated and that is a visible sludge feeding arrangement. All sludge fed into the primary is introduced into a box elevated above the water level in the digester. An operator can observe the density of the feed at any instant and work out a pumping schedule to meet actual conditions.

No valves or other devices require any manipulation during routine operation as all operations are automatic except pumping and withdrawal of sludge.

To conserve critical materials, a concrete instead of steel roof structure has been used. With a dome roof, the amount of reinforcing steel is kept at an absolute minimum.

The second digestion unit developed for wartime conditions is the Single Stage (Type M) unit. This has been adapted from the first stage unit of our Multdigestion System by designing the mixer for intermittent operation. As in the Multdigester, vertical heat exchangers have been included which, with the mixer, insure a high rate of heat transfer. Again steel plate has been eliminated and a concrete dome roof recommended so as to conserve the critical plate for more important war uses.

THERMOPHILIC DIGESTION

Full-scale plants are in operation using two stages of digestion, the first at thermophilic temperature and the second stage at mesophilic temperature. Information regarding this interesting operation will be available during 1943.

DRESSER MANUFACTURING COMPANY

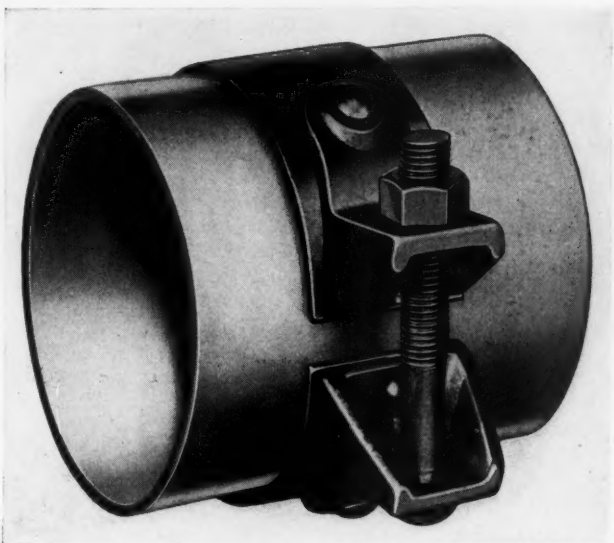
Bradford, Pennsylvania

PIPE COUPLINGS AND FITTINGS, REPAIR CLAMPS AND SLEEVES

NEW CLAMP TO INCREASE PIPE LIFE

Stating that conservation of existing pipe-lines and piping constitutes a challenge to manufacturers and suppliers as well as a major problem to operators and maintenance men, the Dresser Manufacturing Co. of Bradford, Pa., announces a newcomer to its regular line of repair devices—Style 77A Band Clamp, for the quick repair of small pinholes, leaks, and splits in straight runs of pipe.

This new clamp is claimed to be one of the most useful and handy items now available for such repair work. Simple in construction, easy and fast to apply, it



New-Product View: showing Style 77A Dresser Band Clamp for repairing small pinholes, splits, and leaks in pipe.

prevents further damage and loss of line contents where small defects in the line occur.

Style 77A Band Clamp is made up of a heavy, one-piece steel band of circular, split construction, with a riveted bolt lug at each end. A track-head bolt pulls the ends securely. To install, the clamp is sprung apart until it can be slipped around the pipe and over the gasket or packing; then it is bolted up to make a firm, leak-proof repair. A special cone gasket (furnished when specified)

has two molded rubber tabs which aid in positioning the gasket over the pin hole or leak.

An unusual range of sizes is offered. This includes all standard pipe sizes from 1 in. I.D. to 26 in. O.D. Also cast-iron pipe and special sizes. Band widths of 2, 3, 4, and 6 inches may be had. Band thicknesses are 1/16, 3/32, and 1/8 inch.

FLEXIBLE SEWER ROD EQUIPMENT CO.

9059 Venice Blvd., Los Angeles, California

MANUFACTURERS OF A COMPLETE LINE OF UNDERGROUND PIPE-CLEANING TOOLS

In line with its policy of continuous improvement of FLEXIBLE pipe-cleaning tools, Flexible Sewer Rod Equipment Co. introduces the new, improved "Ezy" Rod Reel and Stand, the new Rod Line Puller and the improved Flexible Power Drive.

In designing and improving these tools, FLEXIBLE has had in mind the present need for conserving labor and materials for vital war needs. The entire line of FLEXIBLE pipe-cleaning equipment was developed to eliminate the difficult, hot, insanitary labor previously necessary in this type of work and to make it unnecessary to dig up pavements at important intersections.

EZY ROD REEL AND STAND

The improved Ezy road reel and stand were designed to save time and effort. They do away with the need for stooping, hooking and unhooking when winding and unwinding Flexible rods. When ready for use, in working position, the Ezy rod stand stands at a 45° angle in perfect balance. It is made of rugged, heavy materials, carefully welded to assure the strength needed for rough usage. The center spider is of cast steel to combine lightness with strength. The three legs of the tripod are quickly screwed or unscrewed by hand into the center spider, for quick assembly and for ease in carrying.

FIG. 1.—EZY rod reel and stand.

The Ezy rod reel may be used on trailers without the stand and it is not difficult to improvise a method of mounting the Ezy rod reel on the side of your service trucks.

THE EZY ROD LINE PULLER

Another new labor-saving device is the rod line puller, used to remove rods from the line after it has been worked to the farthest end.

The tube of the rod line puller is made of 2-in. heavy iron pipe, curved to the same radius as the rod guide to prevent bending the rods even on extremely hard pulls. To set up for use, remove the coupling from the joint of the 1½-in. pipe extending down into the manhole, keeping the top of the pipe 2 to 3 in. above the

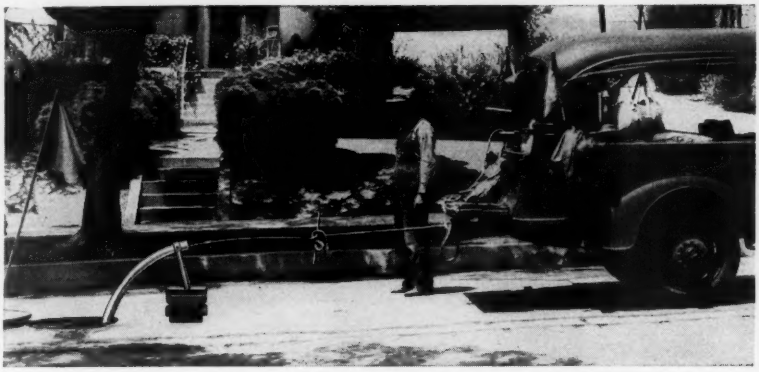


FIG. 2.—Rod line puller.

manhole cover rim. Be sure that the yoke of the rod guide jack is above the lower lip of the cover. Slip the rod line over the 1½-in. pipe until it rests on the guide jack yoke. Tighten the set screws securely. Place the triangle base, as shown in the illustration. Block up the triangle to a level with the hitch on the truck. Fasten the end of the rod to a rope tied to the truck and move the truck forward easily, applying the power slowly and steadily. The rods will be removed in a fraction of the time needed when rods are pulled by hand.

FLEXIBLE POWER DRIVE

The improved Flexible Power Drive saves time and man-power in sewer-cleaning operations. It operated on the same principle as hand turning with ratchet turning handles, but the rod will turn into the line at a continuous speed about five times the speed of hand turning. It is ideal for use in removing roots, scale, sand, mud, slime, sludge, rock and gravel. The power drive is of cast steel to combine lightness with sufficient strength for heavy duty pulling. Equipped with a new type safety clutch, the Briggs and Strattan motor, operating at 1500 r.p.m. applies power through two pulleys at two speeds as well as permitting regulation by the throttle. One lever on the belt pulleys controls all operations—starts, stops and brakes.

By the addition of a universal drive shaft, the motor may also be used to operate large gear operated pipe threaders. It may be hooked up to a 2-in. rotary pump for use in shallow trenches and may be applied to a block and tackle for raising or lowering pipe.

GRUENDLER CRUSHER AND PULVERIZER COMPANY

2915–21 N. Market St., St. Louis, Mo.

Sanitary engineers of municipalities have selected **Gruendler Equipment** to eliminate the nuisance of undesirable material and waste products clogging valves

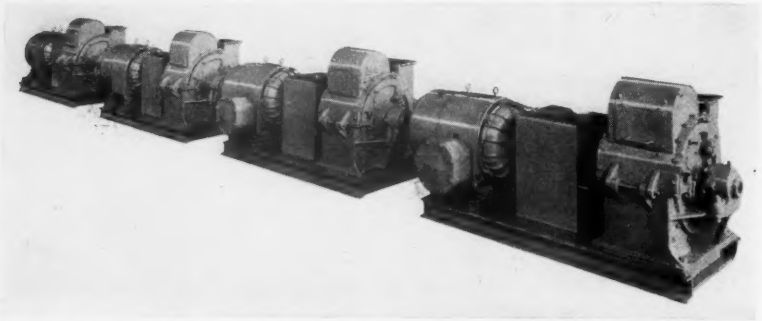


FIG. 1.—Four Gruendler Crusher Units installed at Coney Island, New York, Sewage Plants.

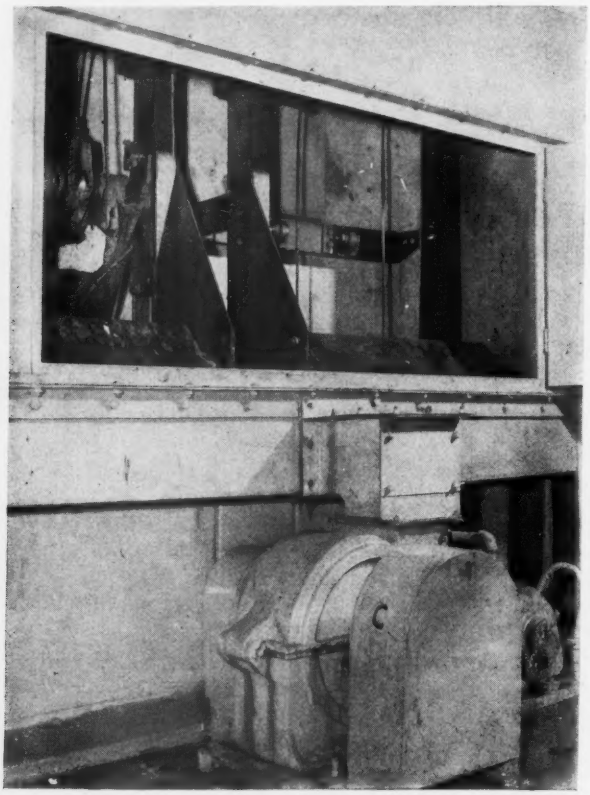


FIG. 2.—Gruendler Sewage Screening Shredder installed at Rutherford, N. J., Sewage Plant.

and sewerage lines. Its new patented features make possible uninterrupted flow notwithstanding frequent quantities of prevailing rag stock. The GRUENDLER SHREDDER is of the wing hammer design with double-end cutting hammers with saw tooth cutting edges revolving inside a cylindrical saw tooth edge shredder plate at 1200 to 1800 r.p.m. Capacities are 500 to 8000 lbs. per hour. Motors are direct connected, and range from 5 to 70 H.P.

The Gruendler Shredder is outstanding because of its patented features such as the *Non Clogging Grid Bars, Safety Tramp Iron Catchers,* and *Improved Water Spray Flushers.*

The Gruendler Sewage Screening Shredder also makes an ideal connection with an incinerator—by grinding, mixing, and preparation in one operation, it prepares product for most efficient combustion and proper feeding.

Gruendler Shredders are dependable and of sturdy construction with sealed bearings to withstand continuous operation. The safety feature of the Gruendler Tramp Iron Catcher is noteworthy, since foreign matter such as cans or metal, which is ungrindable, is easily removed through the access door provided. These shredders are built in many sizes and can be fitted in most difficult plant arrangements, taking a minimum of space and the many designs meet sewage plant operation for higher efficiency. The grinding of sludge to uniform sizes for commercial fertilizer is another operation performed by Gruendler's Hammer-Type Cake Breakers.

Over 150 GRUENDLER SHREDDERS have been SELECTED BY U. S. NAVY as Standard Equipment on BATTLESHIPS and MERCHANT VESSELS.

Blue prints and sewage plant layout, together with specifications, will be gladly furnished by the Gruendler Company. Address Plant and General Offices in St. Louis, Mo.

THE HARDINGE COMPANY

York, Pa.

NEW DESIGN FEATURES ON HARDINGE CLARIFIERS

The special mechanism support bearings now used on all Hardinge Clarifiers are as shown in Fig. 1.

The bearing is of the ring-type ball-thrust design, and is located under the gear rim. In addition to carrying the load of the rotating mechanism, its construction is such that any side sway of the mechanism is prevented. This is accomplished by using a special steel flat ring bolted to the underside of the driving gear during the ball bearing assembly. This ring acts as the outer half of the lower ball-bearing race, and is also designed to absorb any upward thrust caused by undue loadings at the outer end of the clarifier rake arms. The bearings, worm gear teeth, and worm operate in an oil bath, thereby assuring positive lubrication. Worms are of special alloy steel.

The general arrangement of the clarifier, as installed in a concrete tank, is shown in Fig. 2.

The same mechanism bearing is used on all large Hardinge Clarifiers. Figure 3 shows one of three 110-ft. diameter Hardinge units using such a bearing.

Larger Hardinge Clarifiers, which have been installed recently, have used either a concrete pier or a steel column at the center to support the rotating mechanism, and a bridge extending from the side of the tank to the center. The influent pipe is carried on hangers attached to the underside of this bridge.

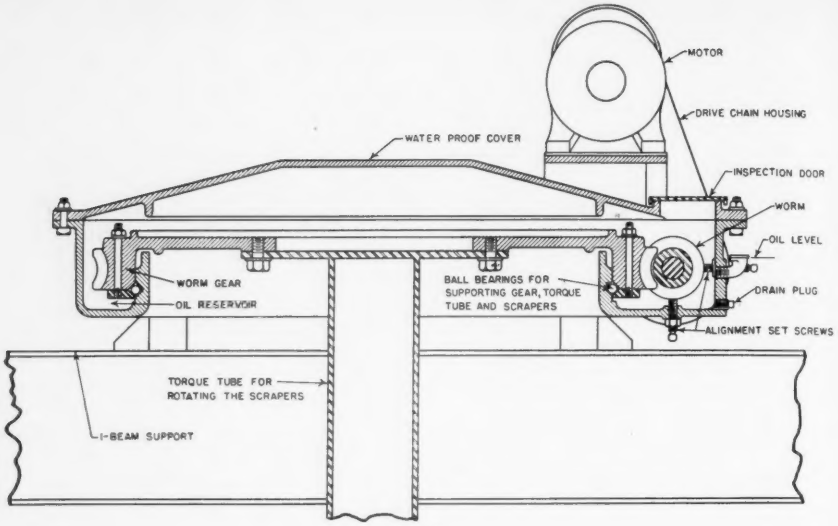


FIG. 1.

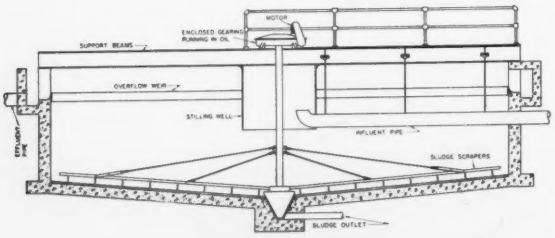


FIG. 2.

FIG. 3.

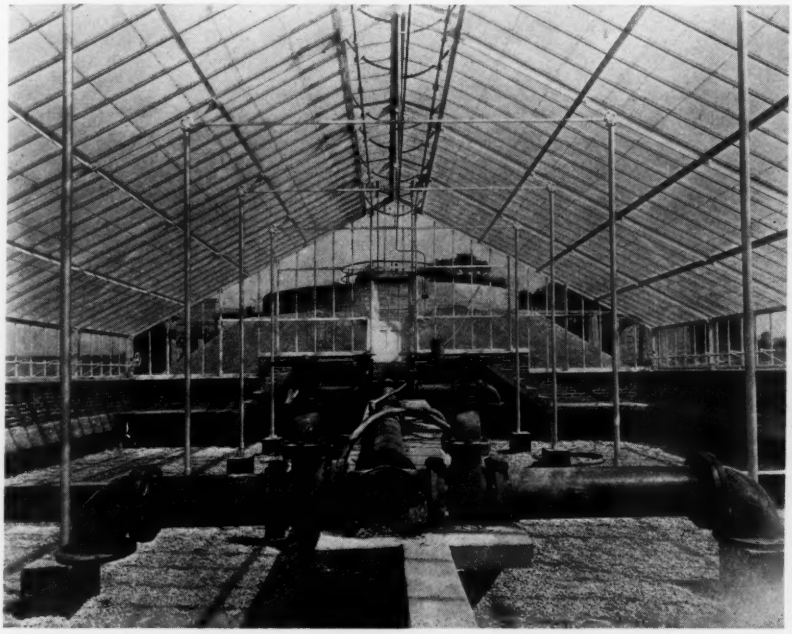
All Center Pier Type Hardinge Clarifiers are arranged with a center drive, and for primary sewage tanks are equipped with an effective skimming device to deliver scum and floating materials into a scum hopper cantilevered from the inside of the tank.

INERTOL COMPANY, INC.

Now at 470 Frelinghuysen Avenue, Newark, New Jersey

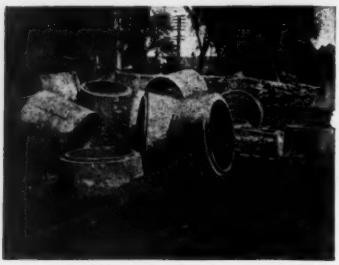
WATERPROOFING AND PROTECTIVE COMPOUNDS

The line of specialized protective coatings for concrete and steel in sewage plants which has been developed by INERTOL COMPANY, INC., during the past sixteen years, has undergone some changes since our country entered the war. The original Ramuc and Glazoflex Enamels, based on synthetic rubber, have been developed for particularly severe conditions, but are now available only for use on Government contracts. In their place, Inertol chemists have developed substitute grades identified by the letters RE (standing for replacement) following the original trade-marks. While these new coatings are not quite equal to the original products, they are rendering good service and complete satisfaction under all but the most severe conditions. If under certain conditions the capacity of these replacement grades to render protection is overtaxed, operators and plant superintendents will have to sacrifice appearance to utility and return to bituminous coatings for good protection, although the latter type of paint is available only in black or dark colors. Although there may be an occasional shortage of



a particular grade of solvent or pitch, no general scarcity need to be anticipated in these raw materials, and INERTOL COMPANY, INC., may be expected to maintain both quality and price of its high-grade bituminous coatings on peacetime levels. By analyzing the particular problems of each customer and by keeping abreast of new developments, INERTOL chemists may be depended upon to

furnish coatings which will meet the requirements of Sanitary Engineers and Sewage Plant Operators.



For full particulars please write to Service Department, INERTOL COMPANY, INC., 470 Frelinghuysen Avenue, Newark, New Jersey, or 64 South Park, San Francisco, California.

INFILCO, INCORPORATED

FORMERLY INTERNATIONAL FILTER CO.

General Offices: 325 West 25th Place, Chicago

GRIDUCTOR

The Griductor, a device for intercepting and cutting sewage solids in the sewage flow, has been much improved through the use of increased diameter rotating discs which provide in effect a coarse screening action, fine screening being provided by the spaces between the discs and the stationary grid as heretofore. Thus some of the coarse solids may be conducted to the cutter bar before reaching the finer screening spaces of the stationary grid.

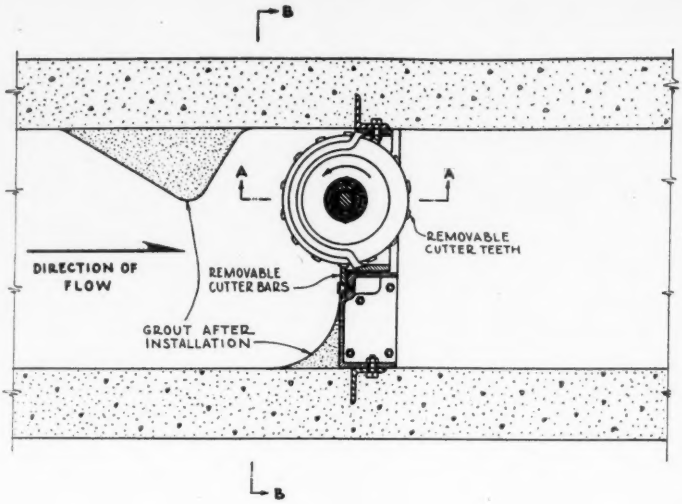
In addition, clearing vanes have been added to the upper and lower faces of each disc, positioned to dislodge any material that may tend to clog the smaller screen spaces between the rotating discs and the stationary grid members. Any material thus dislodged is moved outwardly or upstream from the screen face toward the cutter bar. By this improvement, head losses through the screen element are kept at a minimum and a more uniform cutting load is obtained.

These improvements, together with improved baffling, have served to provide increased operation efficiency of the Griductor and have reduced manual attention required to a minimum.

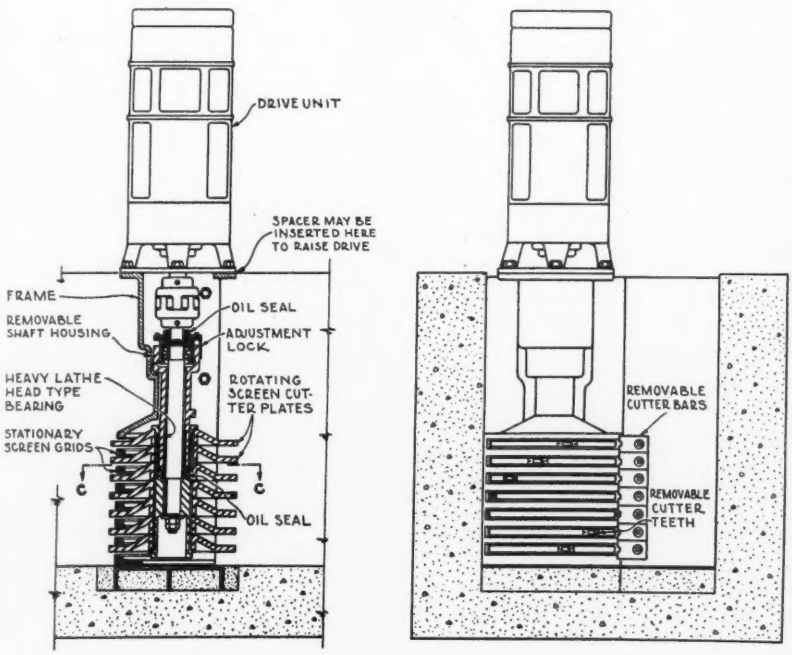
ACCELERATOR FOR SEWAGE

After several years' research, which included operation of a plant-scale demonstration unit over a period of about one year, Infilco is now prepared to offer the well known Accelator for chemical treatment of sewage and industrial wastes.

It will be noted that mixing, coagulation and separation of the coagulated material from the liquor is accomplished in a single tank structure, as contrasted with the conventional mixing tank, coagulation basin and sedimentation tank. Obviously, when chemical treatment of sewage or industrial wastes is indicated, the accelerated action made available by the Accelator will prove dependable and economical.

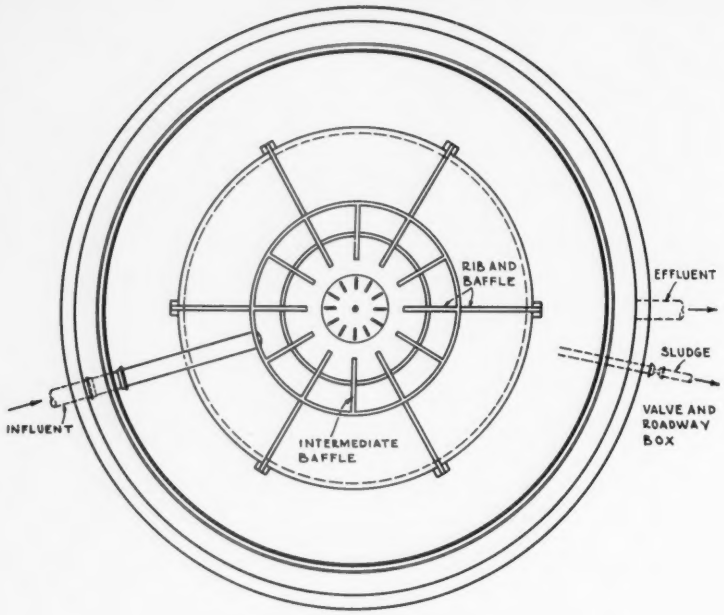


PLAN AT C-C

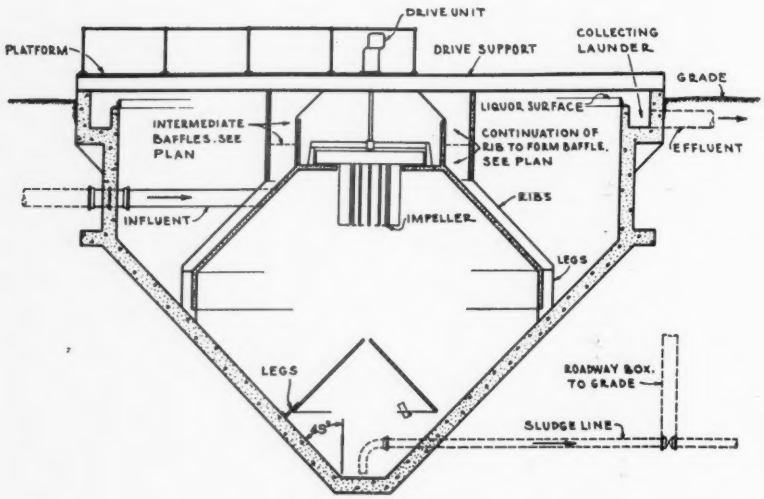


SECTION A-A SECTION B-B

Griductor.

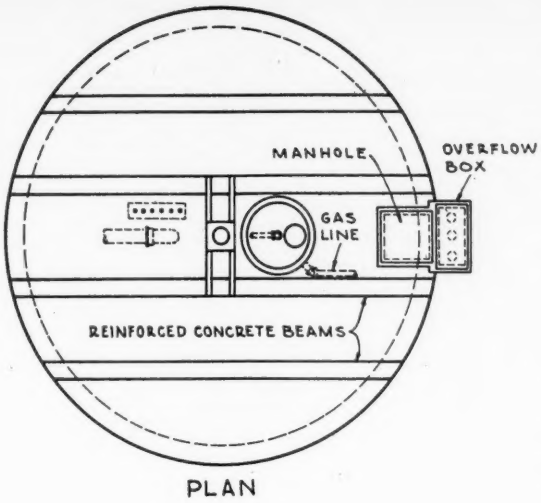


PLAN

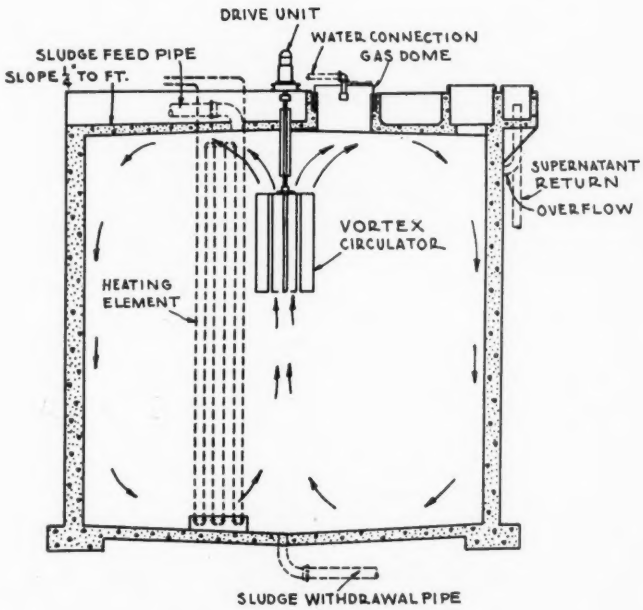


ELEVATION

Sewage Accelator.



PLAN



SECTION THRU TANK

"VC" Digester.

VC DIGESTER MECHANISM

A new Infilco offering for the field of anaerobic sludge digestion is now available in the VC Digester Mechanism. A vortex circulator is used, which provides sufficient disturbance to prevent scum accumulations at the top of the tank and

imparts a radial movement to the tank contents in the lower portion of the tank, which facilitates the formation of a dense sludge for removal. In addition, a spiral movement throughout the central portion of the tank gives adequate mixing essential to good sludge digestion.

LAMOTTE CHEMICAL PRODUCTS COMPANY

Towson, Baltimore, Md.

SPECIALIZING IN THE DEVELOPMENT OF TEST AND CONTROL EQUIPMENT AND MATERIALS FOR THE SCIENTIFIC AND TECHNICAL FIELDS

LAMOTTE MICRO pH TESTING SET, MODEL B

The LaMotte research department has just perfected a new Micro Unit for pH determinations, which offers facilities never before available in the colorimetric system. The basic method has been employed by the LaMotte research department for more than sixteen years, but it was through a recent invention of one of their chemists that the wide application of the procedure was made practicable. In the original procedure, pH determinations on the micro scale were limited to clear and colorless solutions. However, with the new Micro Unit it is now possible to determine accurately the pH of milk, colored extracts and similar solutions, in addition to clear solutions. The important features may be summed up as follows:

1. Requires less than 0.5 ml. of sample.
2. Accuracy $\pm$ 0.1 pH.
3. Turbidity and color in sample does not interfere with the determination.
4. pH range of the standard unit may be extended, if desired.
5. Actual determination can be made in one minute or less.
6. The entire unit is portable and may be set up anywhere.
7. Basic procedure has been time tested and widely used for accurate work.

FIG. 1.—New LaMotte micro pH testing set.

LAMOTTE SLUDGE pH OUTFIT

The special LaMotte Comparator Rack recently developed makes possible the application of pH tests to small samples. This apparatus consists of a small wooden rack, with reflecting mirror base and interchangeable diffusion glass

plates, which are inserted in the rack, as desired. Each plate bears the numerals representing the pH value covered by each of the indicators in the set, in intervals of 0.2 pH. Matched glass cells are furnished for the preparation of the color standards and the sample to be tested. These are compared directly on the glass plates, reading the colorimetric values down through the cells from the top. The effect of color or turbidity in the sample is compensated for by the special arrangement, whereby double readings are made directly, as in the LaMotte Block Comparators, so well known to the industry.

The standard outfit comes complete in a sturdy carrying case, and includes all of the necessary equipment, with instructions for conducting pH tests over the range 5.2 to 8.4. Additional indicators and buffers can be obtained to extend the range as desired at small cost.

FIG. 2.—LaMotte sludge pH outfit.

LAMOTTE-POMEROY SULFIDE TESTING SET

This unit was recently introduced, after considerable cooperative experimental work in conjunction with the method of Dr. Richard Pomeroy. The outfit is offered in its complete form for the accurate determination of (1) total sulfides; dissolved sulfides; hydrogen sulfide in sludges and solutions; and (2) free hydrogen sulfide in air and gases.

The outfit as illustrated includes the standard apparatus for determining total sulfides, dissolved sulfides and hydrogen sulfide, and to the left is shown the ac-

FIG. 3.—LaMotte Imhoff cone stand.

cessory kit (case for same not illustrated) for determining hydrogen sulfide in gases and air. The unit is complete, with everything needed for these determinations, including the special sampling pipettes, which are especially designed and calibrated for the purpose. The ingenious procedure involved in these determinations is based upon the colorimetric system, and is extremely simple to operate.

For the determination of hydrogen sulfide in air and gases a special kit is furnished, to be used in conjunction with the standard outfit. It consists of a graduated aspirator bottle, with fittings, together with the test reagent, all contained in a sturdy carrying case, which permits samples to be taken in the field with the utmost convenience.

The above apparatus will contribute greatly to the convenience and facility with which these determinations can be made.

LAMOTTE IMHOFF CONE STAND

This new stand is of simple, light construction, but is extremely sturdy in service. It was designed as an economical means of facilitating the determination of settleable solids in sewage by the Imhoff method. The cone is held securely in place by a special fiber ring attached to the top of the stand and tapered to afford complete contact with the glass surface of the cone, so that the latter is held rigidly in place. The stand is made to accommodate the standard one-liter Imhoff cones.

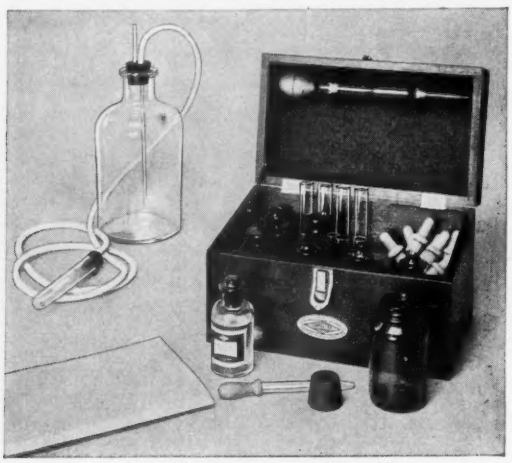


FIG. 4.—LaMotte Pomeroy sulfide testing set.

LINK-BELT COMPANY

2045 W. Hunting Park Ave., Philadelphia, Pa.

307 No. Michigan Ave., Chicago, Ill.

NEWLY DEVELOPED GREASE SEPARATING AND RECOVERY EQUIPMENT

Link-Belt Company has perfected a unique arrangement of aeration, clarifier and skimming equipment for separating and recovering grease from sewage or

industrial wastes. The process employs pre-settling ahead of aeration in order to remove the coarsest solids which might be comminuted in the aeration zone and float with the grease.

Where aero-chlorination is used, pre-settling reduces chlorine consumption by eliminating the immediate chlorine demand of these pre-settled solids. Preliminary settling is particularly valuable in the treatment of industrial wastes for the recovery of grease as a by-product, since it helps to produce a grease having less contamination by floating solids. Furthermore, the detention afforded the flow in the primary settling compartment allows some grease to rise to the liquid surface, from which point it can be skimmed. In the case of recovery of grease from meat packing wastes, the material skimmed from the preliminary compartment is generally "white" grease and is worth about ½c per pound more than "yellow" grease which separates from the liquid following aeration.

The line drawing illustrates a typical installation made at a pork packing and processing plant. In this application the flow from the main plant is not given preliminary settling, because it is more important to give separate pre-settling to the meat processing wastes. The yield of "white" grease is improved and the over-all return justifies, in this specific case, the lack of preliminary settling for the major volume of wastes. However, this separation of wastes and the resulting lack of preliminary settling for part of the flow is unusual.

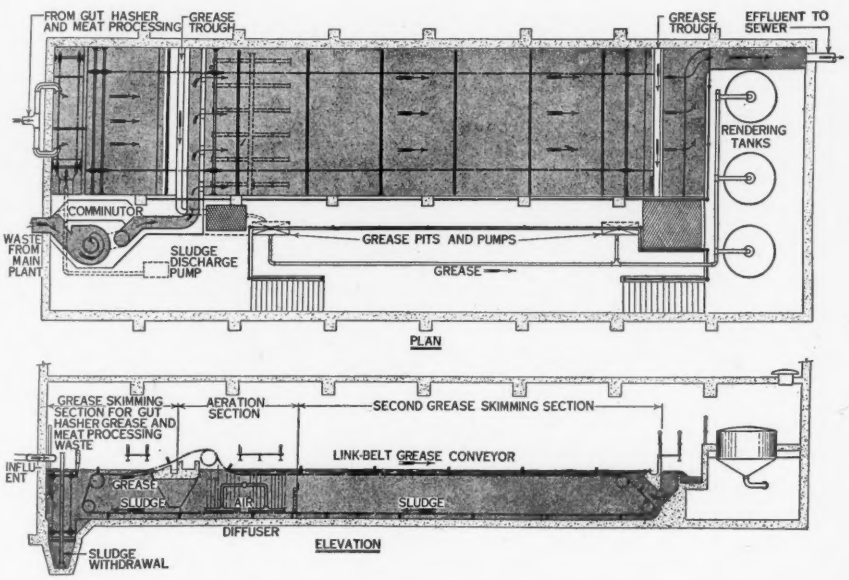


FIG. 1. Grease separating and recovery installation at a pork packing and processing plant in Iowa.

Flow is introduced into the pre-settling compartment behind a rising current of air from two porous tubes submerged in the sewage. The curtain of air acts as a baffle to distribute the incoming flow, and at the same time induces surface currents which carry floating materials into the zone of action of the skimming blades.

Retention periods varying from 5 minutes to one hour are usually provided in the preliminary settling compartment, which is separated from the following aeration section by an under-flow baffle supporting a grease receiving trough above the water surface. Grease which separates and floats here is conveyed into the trough by the upper run of the special straightline sludge collector and scum skimmer.

FIG. 2.—Air diffuser unit.

The same collecting equipment serves as a skimmer in the final settling section as well as to scrape settled material along the floor of the tank into receiving hoppers at the influent end. By utilizing a single mechanism for scum and sludge collecting in both settling sections, economy in first cost is obtained, especially if the secondary settling section also forms the primary sedimentation unit of a subsequent sewage treatment process. In addition, the floor of the aeration compartment is kept clean of settled solids which might subside beneath the zone of action of the air.

Aeration of the liquid is carried on in the intermediate portion of the tank, separated from the preceding and following settling sections by suitable baffles. The volume of the aeration compartment is generally equivalent to 5 to 15 minutes detention of the flow.

Air is introduced into the sewage through porous tubes, made of a corrosion resistant refractory material. The tubes, as shown in Fig. 2, are fed from individual risers emanating from a common header carrying air from the blower. Each riser is provided with a valve for adjusting the discharge in order to obtain uniform distribution of air in the compartment. Air requirements vary from .05 to .20 cu. ft. of free air per min. per gal. of sewage. It has been found best to use a positive displacement type of blower with a variable speed drive for regulating the amount of air delivered.

As shown in photograph and drawing, the conveyor is very similar to the standard straightline mechanisms used with rectangular sedimentation basins. However, the skimming run of the mechanism, as it reaches the end of the first settling section, conveys the grease into the trough, then continues, above the trough and over supporting idler sprockets, back into skimming position in the aeration section.

The driving unit, consisting of a specially designed motorized gear reducer, is located on the sidewall of the tank near the influent end. This same reducer can drive the main sludge collector and skimmer as well as an auxiliary cross-collector, such as shown on the drawing, when the tank is wide enough to need the cross conveyor.

The special skimming and sludge collecting device will not actually deposit grease or scum in the receiving trough located across the tank at the effluent end of the final settling section. Where this equipment is used in meat processing plants, or to treat similar wastes, the accumulation of grease at the end of the tank is deep enough to overflow the grease trough lip when pushed toward it by the conveyor.

However, in plants treating sewage in which the grease content is not so great as in packing plant wastes, either periodic hand removal of scum or a mechanical scum remover is used.

It is believed that this equipment has particular advantages for grease removal ahead of any process employing sedimentation prior to subsequent treatment, because the secondary grease separating compartment and the primary settling tanks can be combined. In some cases the pre-settling compartment of the grease interceptor can serve to remove grit, in which case separate sludge hoppers would be installed across the tank, following the aeration section, to receive the primary sludge. The scrapers would be carried on rails across the sludge sumps. With this arrangement a single sludge collecting and skimming mechanism can serve the grit chamber as well as for grease removal and for removal of primary sludge from the settling tank.

NEW DESIGN OF SLOW MIXER

Mechanical slow mixers are used in modern practice for the coagulation of liquids having finely divided solids in suspension. They are generally arranged parallel to the line of flow through tank and consist of a series of paddles mounted on a horizontal shaft.

The rotation of the paddles builds up a swirling motion in the liquid and brings about the collision and coagulation of the finely divided suspended material. The degree of agitation required to bring about optimum results varies with the characteristics of the liquid treated. It is desirable in the majority of cases

to decrease the amount of agitation as the liquid passes through the mixing tank, in order to build up a more settleable floc.

Another factor in obtaining good mixing is the reduction to a minimum of any short circuiting of the flow through the tank. To this end, it is desirable to break up the "core" of the tank; *i.e.*, the portion of the tank that is concentric with the paddle shaft where the spiral motion of the liquid is a minimum and short circuiting is most likely to occur.

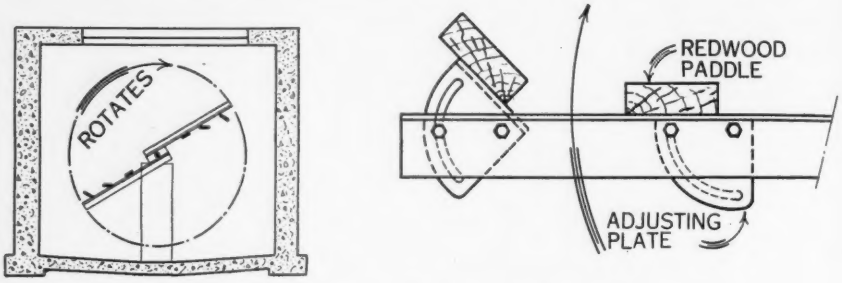


FIG. 3.—Section through slow mixer.
Enlarged view of paddle showing details of adjusting plate.

The use of pivoted flights, as shown in accompanying drawing, gives the installation a flexibility not obtained by the use of fixed flights. By setting the flights at an angle to the direction of travel, the degree of agitation can be controlled throughout the length of the tank without changing the speed of the drive. The pitch of the flights directs the flow toward the "core" of the tank and provides a practically uniform agitation through the entire cross section of the tank.

MABBS HYDRAULIC PACKING COMPANY

431 South Dearborn Street, Chicago, Ill.

RAWHIDE PACKING SAVES VITAL WAR MATERIALS

Using Rawhide Packing in sewage pumps and valves saves vital war materials, as it prevents the wear and cutting of the sleeves, rods, plungers and valve stems. Rawhide Packing is capable of handling very dirty or gritty water without danger

of injury to the metal surfaces. The reason for this is that it never becomes hard or glazed, but always remains too soft to hold the particles of grit upon its surface. These particles either wash away or work back into the body of the pack-

ing, thus protecting the metal surfaces from wear and cutting. "If you do not hold the tool, you cannot cut the metal."

Another important feature of Rawhide Packing, manufactured by the Mabbs Hydraulic Packing Company, Chicago, Illinois, is that it needs no lubrication except water, and when it is wet it's as slippery as an eel and practically frictionless, which results in a marked saving in power. Rawhide Packing also has unusually long life, because where there is no friction, there is no wear.

Taking all these features into consideration: the saving in repairs and labor, the saving in power and the long life of Rawhide Packing, one quickly finds that it is the most economical and desirable packing for the uses mentioned, especially during war-time when every little bit means so much.

NICHOLS ENGINEERING AND RESEARCH CORP.

60 Wall Tower, New York, N. Y.

ENGINEERS, CONTRACTORS, MANAGEMENT

NERCO ACTIVITIES 1941–1942

This year, in an atmosphere of war, members of the Federation of Sewage Works Associations meet in conference on wartime sewage treatment problems.

During the past year Nichols Engineering & Research Corp. has been active in direct war production. Many Nichols Herreshoff Multiple Hearth roaster units are being installed in vital industries. The dependability of this type of furnace, built up over a period of more than 50 years in the mining and metallurgical industries and handed on to the Nichols Herreshoff sewage sludge incinerator, is being called upon in the Nation's war effort.

In the sanitary field, a 14 ft.-3 in. diameter, six-hearth installation for the incineration of digested, activated, elutriated sludge at Cranston, R. I., has been completed. A 16 ft.-9 in. diameter, eight-hearth unit for East Chicago, Indiana will shortly be installed.

The cities of Piqua, Ohio, and Ashland, Ohio, have completed more than a year's regular operation on the incineration of undigested, unfiltered liquid sludge in our Nichols Herreshoff multiple hearth incinerators. At both these plants, the raw sludge from the sedimentation tanks passes to a plain concrete concentration tank, which contains no mechanical equipment and requires no chemicals. Supernatant liquor, which readily separates from the sludge in the concentration tank, is returned to the head of the plant. The concentrated sludge is then fed direct to the incinerator without further dewatering. A marked improvement in efficiency and economy has been obtained because of the simplicity of the operation and at both Piqua and Ashland only one man per shift is required to operate the entire plant. In addition, it has been found that the high heat content of raw sludge is distinctly beneficial to the operation and since the product from the incinerator is an inert mineral ash, the inclusion of digestion is not necessary. The auxiliary fuel required to evaporate the larger quantity of water in the incinerator is greater than when filter cake was incinerated, but the cost of this has been far offset by the many other savings obtained and, at these two cities, there is a substantial saving in power, chemical, labor and maintenance costs.

The operations at Ashland were so successful that the city decided to dispose of garbage as well as sludge at the sewage plant. For this purpose, a grinder,

of the shear type, was installed and two hearths were added to the incinerator to provide the extra capacity required. At the present time, Ashland is disposing of all its garbage and sludge in this manner, the garbage being ground and charged into the incinerator with the sludge.

The incineration of sewage sludge and garbage in one incinerator at one plant provides substantial savings in capital, labor and maintenance costs.

The Nichols Herreshoff sludge drying installation at Dayton, Ohio, has now completed two year's operation. Digested sludge cake from drying beds is dried by means of warm gases admitted at the inlet end of the dryer and exhausted at the lower end. The dried product is granular in texture. The continuous rabbling action of the Nichols Herreshoff dryer provides a large surface for heat contact enabling the drying to be completed with the minimum of fuel and assuring a thoroughly dried uniform product. The same unit can be used for heat drying alone or for drying and incinerating sludge.

PACIFIC FLUSH-TANK COMPANY

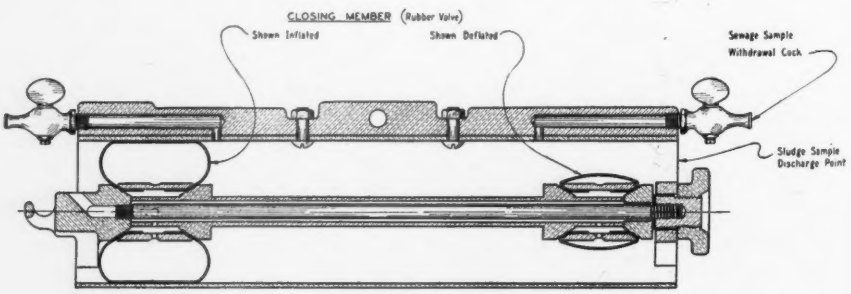
4241 No. Ravenswood Ave., Chicago, Ill.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

Although primarily manufacturers of major equipment for Primary and Secondary Sewage Treatment, the Pacific Flush-Tank Company introduced some months ago a highly practical Sewage and Sludge Sampler. This unit meets a long felt need for a convenient and sanitary sampler. Specimens of still or flowing liquids may be taken without disturbing the liquid bodies or contaminating the samples.

The unit consists essentially of a metal cylinder with an inflatable rubber valve at each end supported at the axis of the cylinder. On the one side of the unit is a sample withdrawal cock and a vent cock. (See sketch.)

The sampler can be used in a vertical position, being passed through the well or hand hole of a digester floating cover or septic tank or it can be used in horizontal position, as shown, to take a sample from an Imhoff Tank or flowing stream. In this case, a detachable guide fin is used.

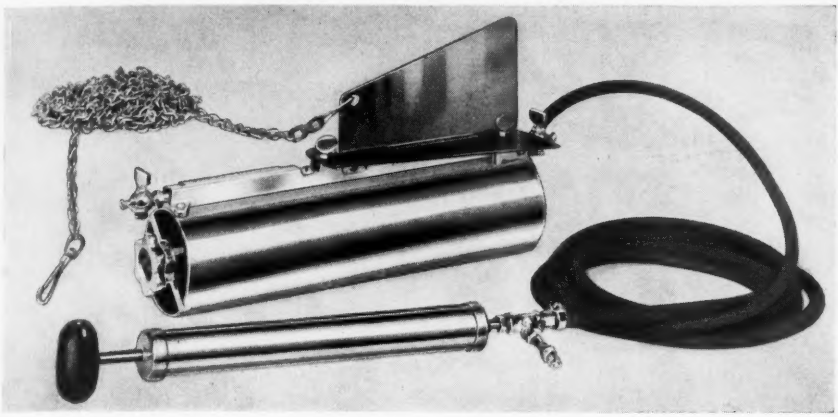


With the valves at both ends deflated, the unit is lowered by means of a chain to the desired depth in the medium to be sampled.

The liquid is allowed to flow through the cylinder for a few moments and the valves are inflated, closing both ends of the unit. A hand pump, supplied, is used and air passes to the balloon valves through a rubber hose, inflating them

simultaneously. After the valves are inflated, the sampler is lifted to the surface and taken to a laboratory or elsewhere for removal through the draw-off cock.

In cases where sludge is to be sampled, the guide fin is not used and the valves are inflated before the unit is lowered to the predetermined depth at which a



specimen is to be taken. This prevents supernatant liquids from entering the cylinder. After immersion in the sludge at the point desired, the air is released from the valves, sludge allowed to enter and the valves once more inflated.

Construction is simple and rugged. All parts are accessible for cleaning or replacement. A new bulletin, No. 133, giving complete details, is available.

ROYER FOUNDRY AND MACHINE CO.

176 Pringle St., Kingston, Pa.

Unlike World War I, many army camps, naval shore establishments and ordnance plants being built today are here to stay. After the last war we disbanded most of our military establishments, but the enemy didn't, obviously.

Since sizable personnel will be maintained indefinitely, key training centers are being outfitted with "all of the comforts of home." Nucleus buildings of a more permanent nature have been erected and sewage treatment, water supply and other facilities afforded the average city have been installed.

The sewage disposal departments of a number of such military establishments, as well as housing projects adjacent to several ordnance plants, have been equipped with Royer Sewage Sludge Disintegrators. A means has thereby been provided for the disposal of the accumulated sludge cake.

The Royer shreds the sludge from the drying beds to pea-size particles, further dries and aerates it, removes sticks and stones and, where desired, mixes in sweetening or enrichening materials such as lime, phosphate or ammonium sulfate. Material can, where desired, be loaded directly into trucks or wheel-barrows.

This properly prepared sludge makes a fine soil builder and lawn top dressing and it is used by the military establishments owning these machines to beautify their grounds.

To facilitate use of the smallest model Royer, called the "Junior," beyond the reach of electrical outlets, the well kept Aberdeen, Maryland, Proving Ground purchased one with a gasoline engine for power instead of the customary electric motor which is standard equipment.

The new "Jr.–G," as the gas driven model has been designated, will be available henceforth where "priorities" and availability of engines permit.

Larger models of higher capacity have been available for some years with gasoline engines, but this type of power on the "Junior-G" Royer is a new departure.

TENNESSEE CORPORATION

619–27 Grant Bldg., Atlanta, Georgia

FERRI–FLOC, a partially hydrated form of ferric sulfate, has been in use in sewage treatment plants throughout the United States for several years, and has proven its many advantages under all types of sewage treatment conditions. The rapid acceptance of this coagulant by the various sewage plants has been due to its numerous advantages over other coagulants now being used in this industry. FERRI–FLOC can be stored readily in either concrete or steel hoppers without any danger whatsoever from corrosion or caking, it can be put into solution with little or no difficulty, can be fed through any standard dry-feed equipment, and has proven itself, through numerous experiments, to be one of the most economical coagulants on the market today.

There is no process in a sewage treatment plant in which a coagulant can be used that FERRI–FLOC has not proven its distinctive advantage. The many uses to which it has been put are conditioning of sludge before it is put on drying beds, conditioning of sludge for vacuum filtration, with and without lime, raw and digested, elutriated and otherwise, as the coagulant in the Guggenheim Proc-

ess, as a coagulant in simple sedimentation, in all types of chemical pre-treatment plants and in the clarification of industrial wastes too numerous to mention.

In further explanation of these various uses to which FERRI–FLOC has been put during the past several years it would probably be interesting to review briefly some of the actual plant findings. In one plant an elutriated sludge, containing approximately 9 per cent solids, was conditioned successfully with FERRI–FLOC and no lime at a dosage of only 1.9 per cent by weight of dry solids. The vacuum filters gave a yield of 10 lb. per sq. ft. per hr. on a dry solids basis. The filter cake contained approximately 70 per cent moisture. In this particular instance FERRI–FLOC has been in use for a period of two years.

In another plant using a well digested sludge, the sludge was conditioned for vacuum filtration by the use of 10 per cent FERRI–FLOC on the dry solids basis, and no lime. This dosage represents a cost of only slightly over 50 per cent of the cost previously necessary to condition the sludge at this plant. Furthermore a very decided saving has been effected due to the fact that conditioning with FERRI–FLOC alone has not necessitated keeping a full time and well trained man to tend the vacuum filters, cloth life has been more than doubled, and the ammonia content of the sludge has not been lowered by conditioning. Since this sludge is used as a soil conditioner and fertilizer, this latter advantage is considered quite important by the plant superintendent.

The dewatering of sludge on standard sand drying beds can often be greatly accelerated by the use of small amounts of FERRI–FLOC. Dosages of only 1 per cent by weight of dry solids are usually sufficient to produce rapid preliminary drying. Since many operators are now finding their drying beds entirely too small to permit proper drying of the increased sludge loadings of the past few years, unsatisfactory lagooning or extensions must be resorted to. By the use of FERRI–FLOC it has been found that the capacity of existing beds can often be doubled at a cost of approximately three cents per ton of dry solids produced.

Increased loadings of treatment plants, particularly by excessive amounts of industrial wastes, have overloaded the primary treatment facilities of many to such a point that they cannot effect a sufficient B.O.D. removal to allow proper operation of the secondary treatment facilities. Due to this fact, FERRI–FLOC has been called upon as an aid in primary treatment. Due to the ability of FERRI–FLOC to form a particularly adsorptive floc over a wide pH range, it has been found very valuable in these overloaded plants due not only to the B.O.D. reduction effected but also to the fact that objectionable trade wastes, which often materially interfere with the secondary treatment process, are removed. As an example of this, FERRI–FLOC has been used in an activated sludge plant for the past year. In this particular instance the sewage often has a B.O.D. as high as 1800 p.p.m. and a pH as low as 3.0. The activated sludge process has not been adversely affected by this variable and strong sewage and it has not been too uncommon for the overall B.O.D. removal in this plant to reach 99 per cent.

FERRI–FLOC is also being used extensively as a coagulant in the Guggenheim Process. In all instances, results have been most gratifying in that an effluent has been economically produced which has shown excellent B.O.D. removal.

Industrial applications are numerous. However, each industrial waste is a separate problem in itself and is studied in detail by the technical staff of the Tennessee Corporation before any recommendations are made. Briefly, packinghouse wastes, cannery wastes, milk wastes, distillery wastes and many others are being successfully treated with FERRI–FLOC at this time.

In conclusion, FERRI-FLOC has taken an important part in sewage treatment and is finding new applications in all types of plants.

UNITED STATES PIPE AND FOUNDRY COMPANY

General Offices: Burlington, N. J.

CAST IRON PIPE FOR SEWERS

The use of cast iron pipe for sewers is steadily increasing throughout the country. Many new sewage treatment plants are being built, some in conjunction with a new sewer system and others to augment an already existing system. Furthermore, major revisions are being made in large numbers of existing treatment plants, not only to increase their capacity but to provide more complete treatment that will produce an effluent of better quality. Treatment costs money; the amount of money is almost directly proportional to the volume treated. Logically, therefore, every gallon of water that seeps into the mains through leaky joints, cracked pipe or from other sources not only crowds the sewer but costs good money to convey it through the various treatment stages.

Cast iron pipe possesses three outstanding properties that are most important for present day sewer construction:

1. Tight pressure type joints that prevent infiltration, thereby reducing treatment costs and incidentally eliminating trouble with tree roots.
2. Compressive strength to resist heavy earth loads due to deep fills over the pipe. Beam strength to withstand stresses caused by earth movement. Bursting strength to resist internal pressure when used as a force main or when pressure might temporarily occur due to floods.
3. Long life that has been proven by years of satisfactory service, consequently permitting a low annual amortization charge on the original investment.

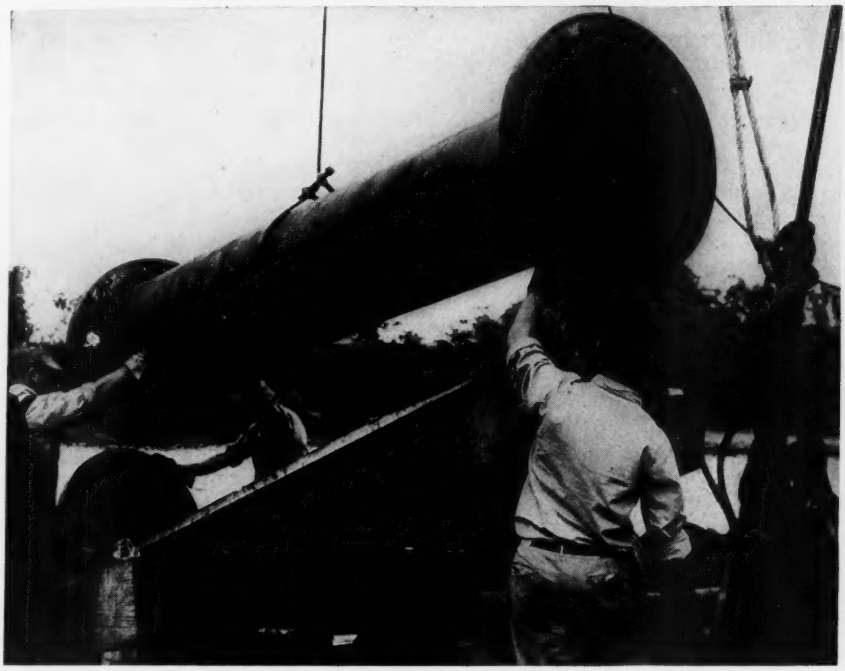
There are many instances in various parts of the country where cast iron pipe has been installed in sewage disposal systems for flow mains, force mains, stream crossings, outfall sewers and in treatment plants.

Cast iron flow lines are generally installed where the pipe are laid in water saturated soil to eliminate troublesome and costly infiltration.

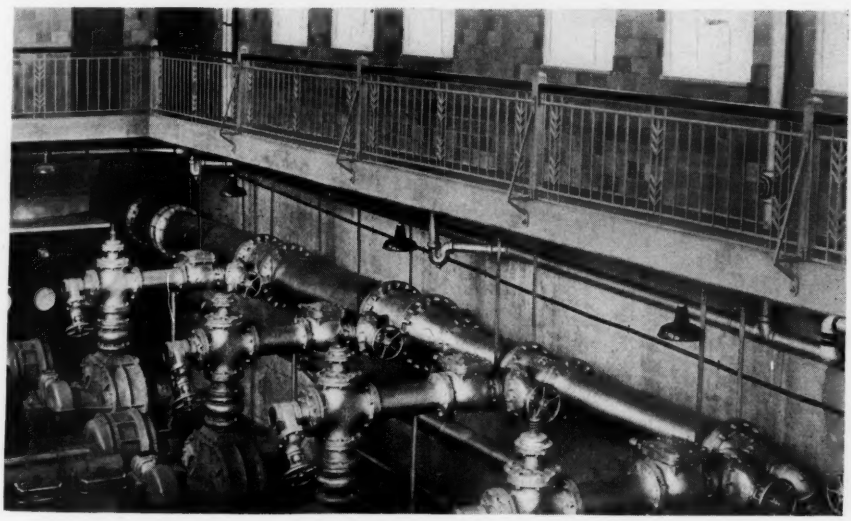
Cast iron force mains are being installed at a steadily increasing rate due to the growing demand for sewage treatment. Treatment plants are usually located some distance away from the more densely populated sections of a community. Frequently, it is not possible to have gravity flow to the plant. In those cases the sewage flows into a sump and is then pumped through a force main to the treatment plant. Illustrated here is a cast iron flexible joint force main being laid on the bottom of a river.

Cast iron outfall sewers have been widely and satisfactorily used to convey sewage, in most cases treated and in some cases untreated, out into a body of water for final disposal.

Cast iron pipe and fittings are used extensively to transport the sewage through the various treatment stages. One of the illustrations shows these products installed in a recently completed sewage treatment plant.



20 in. Usiflex Joint Pipe for sewer force main across river.



Cast iron pipe and fittings installed in a sewage treatment plant.

THE VAPOR RECOVERY SYSTEMS COMPANY

Main Office and Factory: 2820 North Alameda St., Compton, California

"VAREC" EQUIPMENT CONSULTANTS, DESIGNERS AND MANUFACTURERS OF GAS CONTROL AND TANK EQUIPMENT

With many years experience in the gas control and safety equipment manufacture, The Vapor Recovery Systems Company has developed a line of gas control safety devices for sewage treatment works that embody the latest engineering designs in this field. Sewage disposal units today incorporate operating gas control refinements comparable to the most highly specialized process plant installations in the world.

In the Multiple Digester Gas System, "VAREC" approved pressure relief and vacuum breaker valve with flame arrester is installed on the digesters and gas storage tanks to maintain system operating pressure and to protect the vessels in case of fire from without. Being constructed of aluminum throughout, they are noncorrosive, easily inspected, and maintained.

"VAREC" approved flame traps are installed throughout wherever there is a possibility of fire inside the plant piping. These units are made of corrosion resisting aluminum and afford a positive flame stop. All "VAREC" flame arresters are approved by the Underwriters' Laboratories.

To maintain system pressure at the waste gas burner, a "VAREC" pressure relief and flame trap assembly is installed. This unit consists of a sensitive diaphragm—operated regulating valves in conjunction with a "VAREC" flame arrester, into which a thermally operated by-pass valve is built. In case of fire in the system, this by-pass valve automatically closes the regulating valve providing a positive flame check.

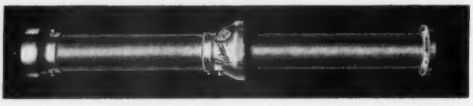


FIG. 1.—"VAREC" approved waste gas burner.

"VAREC" approved waste gas burners (Fig. 1) are manufactured with a wide capacity range and are furnished either with or without pedestal mounting, as required. The pilot valve gas line is protected by the installation of a "VAREC" approved flame check.

To handle sudden surges in pressure due to explosions or momentary plant fluctuations a "VAREC" approved explosion relief valve is installed in the system. Being dead weight loaded, it insures a positive and foolproof relief valve.

In plants where the gas is used to operate boilers, engines or other equipment, a "VAREC" approved pressure regulating valve is installed in the gas line to each piece of equipment. These valves are set to operate at a lower pressure than the "VAREC" pressure relief and flame trap unit, thus making sure that all the gas required is available for useful work before any is allowed to go to the waste gas burner.

"VAREC" approved manometers are used through the plant for indicating system pressure. They are obtainable in single or triple reading units with or without push button control. This later feature is a built-in push button type valve that keeps the manometer shut off until the button is pushed. It is another

"VAREC" engineered feature incorporating safety devices for should the manometer glass break, no dangerous gas is allowed to escape from the system.

One of the basic design fundamentals in gas plant engineering is to keep the lines drained and free from moisture. A full line of "VAREC" approved sediment traps and condensate drip traps is available to meet this requirement.

The "VAREC" approved check valve is required in a system operating at low pressure. Designed for this purpose, its aluminum clapper cutting down the pressure required to keep it open.

"VAREC" non-sparking and gas tight manhole covers, installed on all tanks, provide a quick entry into the tank (Fig. 2).

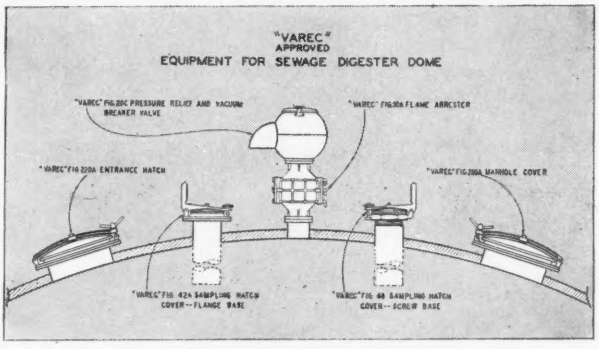

"VAREC"
APPROVED
EQUIPMENT FOR SEWAGE DIGESTER DOME
"VAREC" FIG.20C PRESSURE RELIEF AND VACUUM BREAKER VALVE
"VAREC" FIG.30A FLAME ARRESTER
"VAREC" FIG 220A ENTRANCE HATCH
"VAREC" FIG.220A MANHOLE COVER
"VAREC" FIG 42A SAMPLING HATCH COVER--FLANGE BASE
"VAREC" FIG 40 SAMPLING HATCH COVER--SCREW BASE

FIG. 2.—Equipment for sewage digester domes.

"VAREC" gauge and sampling hatches are also gas tight and non-sparking and have a foot pedal design to facilitate taking samples and gauges.

All "VAREC" regulating and control equipment is flow tested in the most modern type laboratory. Curves are published from each piece of equipment and can be used to determine the most economical size for each specific installation.

WAILES DOVE-HERMISTON CORPORATION

General Offices: Westfield, New Jersey

PROTECTIVE COATINGS FOR INDUSTRY

FIVE YEAR SEWAGE PLANT TESTS OF PROTECTIVE COATINGS

Around a sewage plant corrosive conditions for steel, iron and cement, and coatings to protect them, are about as severe as can be found. In order to determine the comparative protective value of various paints and coatings in actual service, tests have been conducted for almost five years at one of the country's modern sewage disposal plants.

The sewage at this plant is particularly destructive to improperly protected steel, iron and concrete—evidenced by the fact that the concrete and such metal parts as manhole covers (painted with asphaltum) already show marked deterioration and corrosion.

The test consisted of suspending in the sewage steel angles about 2 in. by 2 in. by ¼in. and concrete cylinders 8 in. in diameter by 12 in. high, coated with various paints and coatings, including our own Bitumastic products.

The tests were started in December, 1936. Some of the test specimens were placed in a channel near the Chemical Building and some in a basin or sump into which raw sewage runs for pumping into the plant.

As further evidences of the especially destructive effects of this sewage the galvanized steel cables (approximately ⅜ in. in diameter) that were used to support the test specimens, corroded so badly that they had to be replaced three times during the period from December, 1936, to August, 1939. At that time stainless steel cables were substituted. As it was impossible to secure stainless steel cable clamps, the ordinary galvanized clamps were used. The last inspection in July, 1941, showed the stainless steel cables unaffected but the galvanized clamps at one end of the supporting timber had corroded so badly in the two year period that this end had dropped into the sewage channel.

Periodic inspections were made of the specimens at the two locations. The third inspection at location A in June, 1939—(30 months after installation) showed that all specimens had fallen into the channel because of the corrosion of the galvanized cables. This had occurred some time after the second inspection—12 months after installation. However, some very interesting results were disclosed before these specimens were lost.

Some additional specimens were installed at location B in August, 1939, where some of the original specimens were installed in December, 1936, many of which still remain.

The tests disclose that the sewage was very destructive to conventional paints and coatings that are often used around sewage plants. The failures of these well known and extensively used materials naturally makes more impressive the performance of the Bitumastic products which have withstood the corrosive conditions, with no deterioration of the coating materials or of the steel or concrete to which they were applied. *These Bitumastic products are the only ones of the many included in the tests that have an almost perfect record to date.* We will be pleased to forward details of the experimental data on request.

WALLACE & TIERNAN CO., INC.

Newark, N. J.

CHLORINE CONTROL AND CHEMICAL FEED DEVICES
POTENTIAL CONTROL—AUTOMATIC CHLORINATION OF SEWAGE

During the past several years progress in the science of sewage treatment has been extensive. Numerous discoveries and improvements have been made in treatment processes as well as in the various types of equipment for treating and conditioning sewage. Today the selection of a sewage treatment process and the design of a treatment plan is contingent upon careful studies of duly accredited methods and equipment to best fulfill the requirements of the particular problem at hand.

In step with this progress in the art of sewage treatment in general are the advances in sewage chlorination technique and methods. The character of sewage and the unpredictable variations in its strength as it arrives at the treatment plant are problems which have always confronted the engineer and plant operator. It is quite easy to determine the quantity of sewage flowing through the plant at any one time but it is quite another thing to determine the strength, or

chlorine demand of this same sewage. These two factors—quantity and strength of sewage—together determine the total amount of chlorination required for adequate treatment. Ordinary methods of control are not able to follow the changes usually encountered in these two variables.

Only recently has it been possible to determine the maximum and minimum values of chlorine demand and to follow changes as they occur. The practice of chlorinating sewage to realize 70 to 90 per cent satisfaction of the chlorine demand at all times is recognized as an accepted method of chlorination, particularly on large scale installations where the quantities of chlorine consumed are considerable. Unfortunately, control has, in most cases, been based upon a very limited knowledge of actual conditions. In some instances an approximation of conditions existing at any particular time has been based upon frequent laboratory determinations of chlorine demand. This procedure is expensive and in most cases is not practicable.

Wallace and Tiernan research and development have now made it possible to obtain a continuous record of these changes in sewage quality. These records indicate the actual chlorine requirements at all times regardless of changes in flow or chlorine demand.

The basis of this new control device is the electrical potential of the chlorinated sewage. Automatic recording of this potential has revealed many new and interesting phenomena in the field of sewage chlorination. The effect of storm flows and other unusual conditions on the chlorine requirements of sewage have been clarified through studies of these records. The wide variation in total chlorine requirements due to the combined effect of flow and chlorine demand has in many instances exceeded the expectations of Wallace & Tiernan research men who have specialized in sewage treatment for years. Of particular significance is the finding that neither the pattern nor magnitude of the variations in total chlorine required are consistent from day to day, but change considerably in both respects.

The need has long been felt for a method of automatically controlling the chlorination of sewage. Utilizing an entirely new principle of operation Wallace & Tiernan Potential Control has been developed to meet this need.

HOW IT WORKS

The term "oxidation" is frequently referred to when speaking of sewage treatment. One way to oxidize sewage is to chlorinate it. The nature of sewage and the organisms found therein is such that there is a tendency to "deoxidize" or reduce the sewage. The extent to which this reduction has taken place depends primarily upon the age, temperature, and concentration of the sewage and therefore the "degree of oxidation" of the sewage bears a relationship to its condition.

Wallace & Tiernan Sewage Potential Control takes advantage of this characteristic of sewage. A small sample of sewage continuously flowing through a cell produces an electrical potential between the cell electrodes which varies with the condition of the sewage. These variations in the potential of the sample stream are automatically recorded on a chart. Weak sewage, or sewage in which reduction has made little progress, exhibits a relatively higher potential than sewage oxidized either to a lesser degree or one in which considerable reduction has taken place. The addition of chlorine to the sewage lowers its avidity for oxygen and increases its electrical potential.

The control device is so designed that it may be set to maintain any desired potential in the sewage after treatment. When deviations from this potential occur, adjustments are automatically made to a Wallace & Tiernan vacuum chlo-

rinator to restore the potential to its control setting. Thus the rate of chlorine application is always such that a constant electrical potential is maintained in the sewage flowing through the plant and this application is in step with the chlorine requirements of the moment.

Potential control is therefore fully automatic. Rates of chlorine application correspond to actual chlorine requirements resulting from changes in the two variables—quantity and quality of sewage. Potential characteristics of sewage, both domestic and industrial, are such that the control may be set to maintain chlorination at some level below the immediate chlorine demand of the sewage. Taking advantage of this fact, a number of plants control at a potential level corresponding to approximately 70 to 80 per cent of chlorine demand satisfaction, thus realizing considerable savings in the cost of chlorination.

FACTORS AFFECTING CHLORINE REQUIREMENTS

The factors which determine the chlorine requirements at a sewage plant are many. Size of collecting system, steep or flat sewer grades, presence or absence of dissolved oxygen and industrial wastes, all of which influence general sewage characteristics, also play their part in determining the chlorine demand of the sewage when it arrives at the plant. At some treatment plants the variations in flow may be very moderate, in which case changes in chlorine demand alone would determine to a large extent, the chlorine requirements. At other plants variations in flow may be quite extensive throughout the day. At such plants, regulation or chlorinator rates in accordance with these changes in flow is a step in the right direction. When considerable variations in both flow and strength of sewage occur, the problem of chlorine control is naturally more complex. Storm flows and other unusual conditions add to this complexity.

ADEQUATE TREATMENT AT MINIMUM COST

Obviously any means of control has all of these factors to contend with. The precision of control therefore depends upon the particular method employed to regulate rate of chlorination. For most efficient treatment it is not sufficient to adjust the chlorinator to feed at one constant rate during the day hours and another constant rate during the night hours. Better and closer control is possible with automatic types of chlorinators which will follow changes in flow, thus integrating one of the two variables—or chlorinators programmed on a step-by-step basis. The ideal control method, however, is one which will continuously integrate both variations in sewage flow and chlorine demand. Such control is possible with W. & T. Potential Control Equipment.

Chlorination of sewage thus takes on a new significance with the advent of this method of automatic control. In addition to accurate regulation of chlorinator feed rates, potential control assures adequate treatment at all times with a minimum use of chlorine.

Wallace & Tiernan research and development have again produced a tool useful to the plant engineer and operator. New concepts of sewage chlorination have been revealed by this device which has been aptly termed "The Chlorine Watchman at the Sewage Plant."

WORTHINGTON PUMP AND MACHINERY CORP.

General Offices: Harrison, New Jersey

SEWAGE PUMPS

One of the important problems in the design of centrifugal pumps for handling raw sewage is to provide ample clearance through the impeller to prevent clogging without an excessive sacrifice in efficiency.

This has been accomplished for pumps in the smaller capacity range by increasing the width of the vanes at the periphery of the impeller, also the width at the throat of the volute casing. The number of impeller vanes is also limited, usually to two vanes, to increase the space between vanes.

As this design violates many of the principles of good hydraulic practice used in pumps for handling clear water, it is to be expected that efficiency must be sacrificed. The range of sizes for which such compromise designs are necessary requires comparatively small horsepower for operation. The lower efficiencies are therefore justified by the more reliable operation obtained.

In the larger sizes of this same type of pump, less compromise is necessary in hydraulic design to obtain the required area through the water passages. The efficiency will therefore be closer to that obtained with well designed pumps for handling clear water.

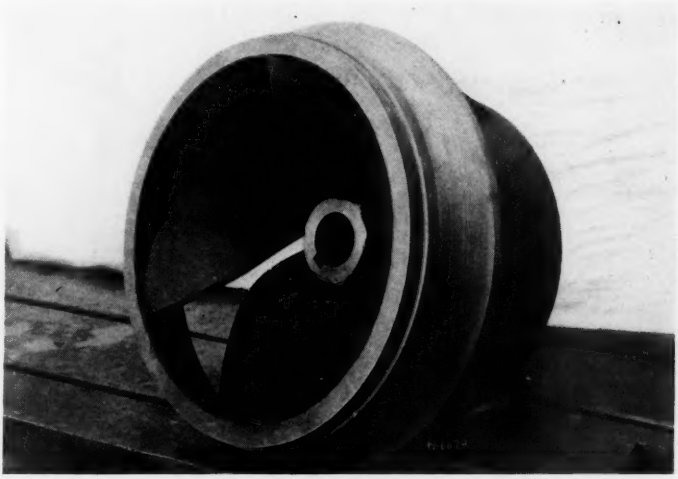


FIG. 1.—Three-blade type inclosed impeller, similar to two-blade type developed for sewage pumping.

All pumps of the smaller sizes (up to 8 or 10 in.), should be a low specific speed type having comparatively large diameter impellers in order to keep the rotative speed within reasonable limits. For pumps of larger unit capacity (above 10 in.), the specific speeds can be increased without exceeding reasonable rotative speeds.

For many years pumps of the mixed flow type have been used successfully for handling raw sewage. Due to higher specific speeds inherent with pumps of this type, impeller diameters are naturally smaller than those for the conventional volute casing centrifugal pump. Increased width at the impeller periphery to obtain equivalent capacity is therefore in line with good hydraulic practice to obtain a proper velocity of flow from the impeller into the pump casing. In

the larger units of this type, very little change from the standard impeller design has been necessary to obtain successful operation in sanitary service.

In the border line sizes above the range of the lower speed non-clog pump, the standard impeller design for the mixed flow pump is not satisfactory for handling raw sewage. To solve this problem, Worthington Engineers have developed a special two-vane enclosed type impeller that has now been used with very satisfactory results in many installations of mixed flow sewage pumps.

The advantages of the two types of sewage pumps are therefore combined in a single unit with a minimum sacrifice of efficiency to obtain non-clog characteristics. Smaller diameter casings permit a reduction in the size and cost of the pump well, and the higher rotative speeds increase both pump and motor efficiency, thus reducing the cost of operation.

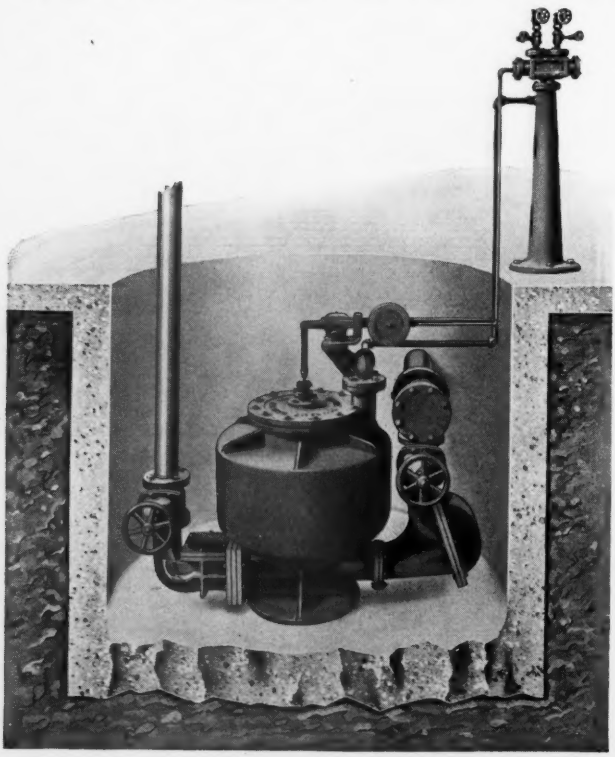
YEOMANS BROTHERS COMPANY

1433 N. Dayton Street, Chicago, Illinois

MANUFACTURERS OF YEOMANS PUMPS, SHONE SEWAGE EJECTORS, YEOMANS SEWAGE EXPELSORS, ROTARY AIR COMPRESSORS AND VACUUM PUMPS, SEWAGE TREATMENT EQUIPMENT

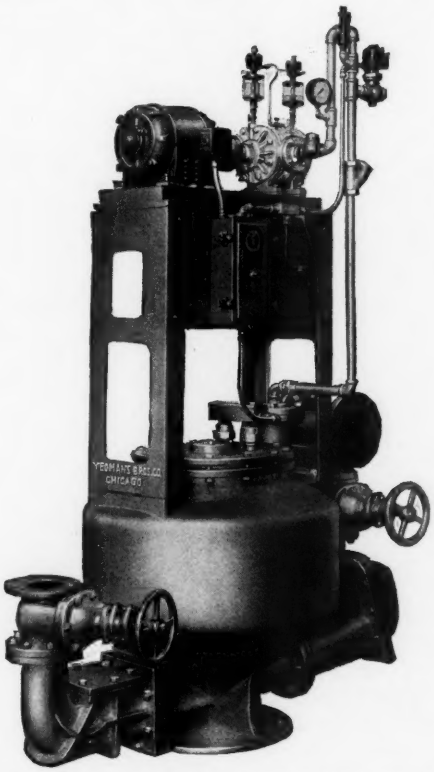
YEOMANS INTERLOCKING CONTROL FOR DUPLEX PNEUMATIC SEWAGE EJECTORS

The pneumatic sewage ejector was invented and patented *circa* 1870, by Sir Isaac Shone, a noted English sanitary engineer of that period. The present-day



Yeomans-Shone type "SDV" pneumatic sewage lift station.

Shone Sewage Ejector stems from that source and the basic principle upon which it operates has remained unchanged throughout the intervening 70 years or more. During that time thousands of sewage ejectors bearing the Shone name have been installed in almost all parts of the world. The first installation in this country in the Auditorium Hotel and Theatre, Chicago, consisting of several duplex sets imported from England, was made when that historic building was erected in 1889. These machines are still in service today and the total cost of maintenance has been practically nil.



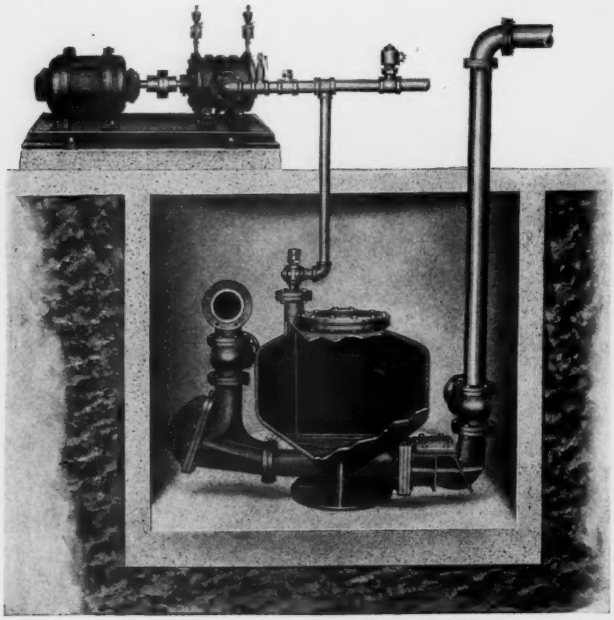
Yeomans-Shone "package" type pneumatic sewage lift station, with ready-mounted rotary air compressor, motor, automatic control, pipes, valves and fittings.

The Shone Ejector is therefore very old; probably one of very few pieces of mechanical equipment still in operation after so many years of service. But in another sense, it is also very modern because improvements conforming to progress in mechanical, hydraulic and electrical development have been introduced repeatedly.

Among the latest of these innovations are Yeomans interlocking devices to provide consecutive discharge of two ejector units in a duplex installation by preventing simultaneous ejection. In Shone Ejectors of the "SEC" type and Yeomans Sewage Expelsors, employing the most modern type of electric air control, in which stationary electrodes located in hermetically sealed receivers are used, this is accomplished by means of electrical interlocks. However, in the case

of ejectors of the Shone type "S" or "SDV," in which mechanically actuated air and exhaust valves are employed, and which are peculiarly suited to installation in underground vaults and to operation from existing plant air service, a mechanical interlock is required to prevent simultaneous discharge of the two units. This is accomplished by means of a pneumatically operated shut-off valve installed in the pressure line to the piston air valve of one unit and operated by pressure from the other unit.

It is obvious that after each ejection of the sewage receiver, the air pressure must be shut off and the receiver vented to atmosphere to permit refilling for the next discharge. That being the case, the contents of the receiver must be expelled in not over thirty seconds in order to maintain continuous operation of the ejector at its rated capacity in gallons per minute. That again means that the rate of



Yeomans-Shone type "SEC" pneumatic sewage lift station; air compressor separately mounted.

flow in the discharge line in gallons per minute will be twice the rated capacity of the ejector in gallons per minute and if the two ejectors discharge simultaneously, the flow rate in the discharge line will again be doubled. It is therefore desirable in many installations to use the interlocking device as a means of smoothing out flow and holding down friction losses in force mains.

The Yeomans interlocking devices of both the mechanical and electrical types are not intended to produce exact alternation of the two units of the duplex ejector, but that is in no way essential to satisfactory service and, under normal conditions, alternate operation will prevail most of the time. When the inflow equals the capacity of the two units a continuous flow in the discharge line will be maintained. The arrangement of air and exhaust valves in the Shone mechanically controlled ejectors is especially adaptable to interlocking operation.